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Geomorphology of the Connecticut River, Glastonbury Reach, as a Spatial-Temporal Context for Understanding Pre-contact Settlement Patterns

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Geomorphology of the Connecticut River, Glastonbury Reach, as a Spatial-Temporal Context for
Understanding Pre-contact Settlement Patterns

Jaime Lynn Grant, PhD

University of Connecticut, 2015

The research upon which this dissertation was based integrated Geographic Information Systems (GIS), alluvial geomorphology, and sediment analysis with archaeological settlement pattern analysis in the Glastonbury Reach of the Connecticut River Valley. The primary objective of this research was to identify the alluvial geomorphic filters that obscure remnant settlement patterns and in so doing refine our understanding of Pre-contact settlement systems during the Archaic Period and Woodland Periods, a time of environmental change followed by settlement and subsistence shifts.

Statistical analysis of Connecticut's site distribution, historic planform analysis and partial reconstruction of the Glastonbury Reach during the Woodland Period revealed patterns in the Late Archaic through Woodland Periods (5000–300B.P.) floodplain site distributions. This research demonstrates that the development of a meandering alluvial reach coincided with a shift in settlement that began in the Late Archaic Period. Furthermore the Pre-contact planform reconstructions demonstrated that the Terminal Archaic through Middle Woodland archaeological site distributions were the most impacted by changes in the shape and location of the meanders. However, the last meander bend of the Glastonbury Reach was constrained in movement and therefore the archaeological site distribution within in it is a good representation of settlement patterns created from the Late Archaic through the Late Woodland Periods. Examination of this archaeological site distribution revealed a settlement preference for the ridge landforms created by the meandering river. This trend began in the Late Archaic Period and continued through Woodland Period, where it culminated in semi-sedentary villages, such as the Morgan Site, around 1000 A.D.

This settlement shift and preference for landforms created by the meandering river is visible in other alluvial meandering systems, such as Reach 11 of the Housatonic River and the Windsor Reach of the Connecticut River. Several potential explanations for this settlement shift and landform preference are examined in this thesis. The initial settlement shift to large alluvial river valleys appears to have coincided with the development of a stable meandering floodplain as well as increased erosion in small perennial streams as a result of climate change and sea level rise. The preference for ridge and swale topography, created by a meandering river, may have developed in order to utilize these raised landforms to grow weedy cultivars such as *chenopodium*. It is possible that this settlement shift may have been the precursor to the adoption of maize-based horticulture. Thus far the only sites to have evidence of weedy cultivar use and maize horticulture are riverine sites.

This research presents and discusses the Late Archaic through Woodland Period archaeological within a diachronic context. Fundamentally it demonstrates the utility of incorporating landform studies at a medium scale to identify and examine the impact of one set of defined variables on another.

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Understanding Pre-contact Settlement Patterns

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B.A., University of Evansville, 1999

M.A., University of Connecticut, 2002

A Dissertation

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at the

University of Connecticut

2015

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Jaime Lynn Grant

APPROVAL PAGE

Doctor of Philosophy Dissertation

Geomorphology of the Connecticut River, Glastonbury Reach, as a Spatial-Temporal Context for
Understanding Pre-contact Settlement Patterns

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Chapter One: Introduction

1.1 Landscape Perspective and Archaeological Settlement Patterns

The purpose of this dissertation is to adopt a landscape approach in the study of Connecticut's archaeological site distribution in a segment of the Connecticut River Valley, identified as the Glastonbury Reach, which extends from Hartford Connecticut to a bedrock fault line in Rocky Hill Connecticut (Figure 1.1). The landscape approach in archaeological investigations incorporates regional geomorphology, taphonomy, formation processes, and ethnoarchaeology with a landscape perspective to examine the archaeological record. The landscape perspective embodies the view that the study of the distribution of archaeological artifacts and features relative to the elements of the landscape (and not merely the spatial relationships among the artifacts and archaeological features), provides insight into social and economic organization in the past (Rossingnol: 4, 1992).

The central hypothesis of this dissertation is that during the Late Holocene the inception of a meandering alluvial river and floodplain in the Glastonbury Reach coincided with a settlement and subsistence shift. This research examines the relationship between the floodplain's ridge and swale topography, created by the meandering river, and the archaeological site distribution. It is hypothesized that from the Late Archaic through the Late Woodland, inhabitants sought out these floodplain ridges. Previously recorded archaeological sites were identified as situated on ridges that are less than 10m wide and hundreds of meters long (Dewar and McBride 1992; McBride 1978). However, this distribution was thought to be the product of differential preservation. This dissertation identifies what portions of the archaeological settlement pattern have been impacted by the meandering river and in so doing demonstrates that

the sites situated on the floodplain ridges are reflective of a settlement system shift.

Archaeological site distributions that were created by both cultural and natural processes are termed remnant settlement patterns (Dewar and McBride 1992).

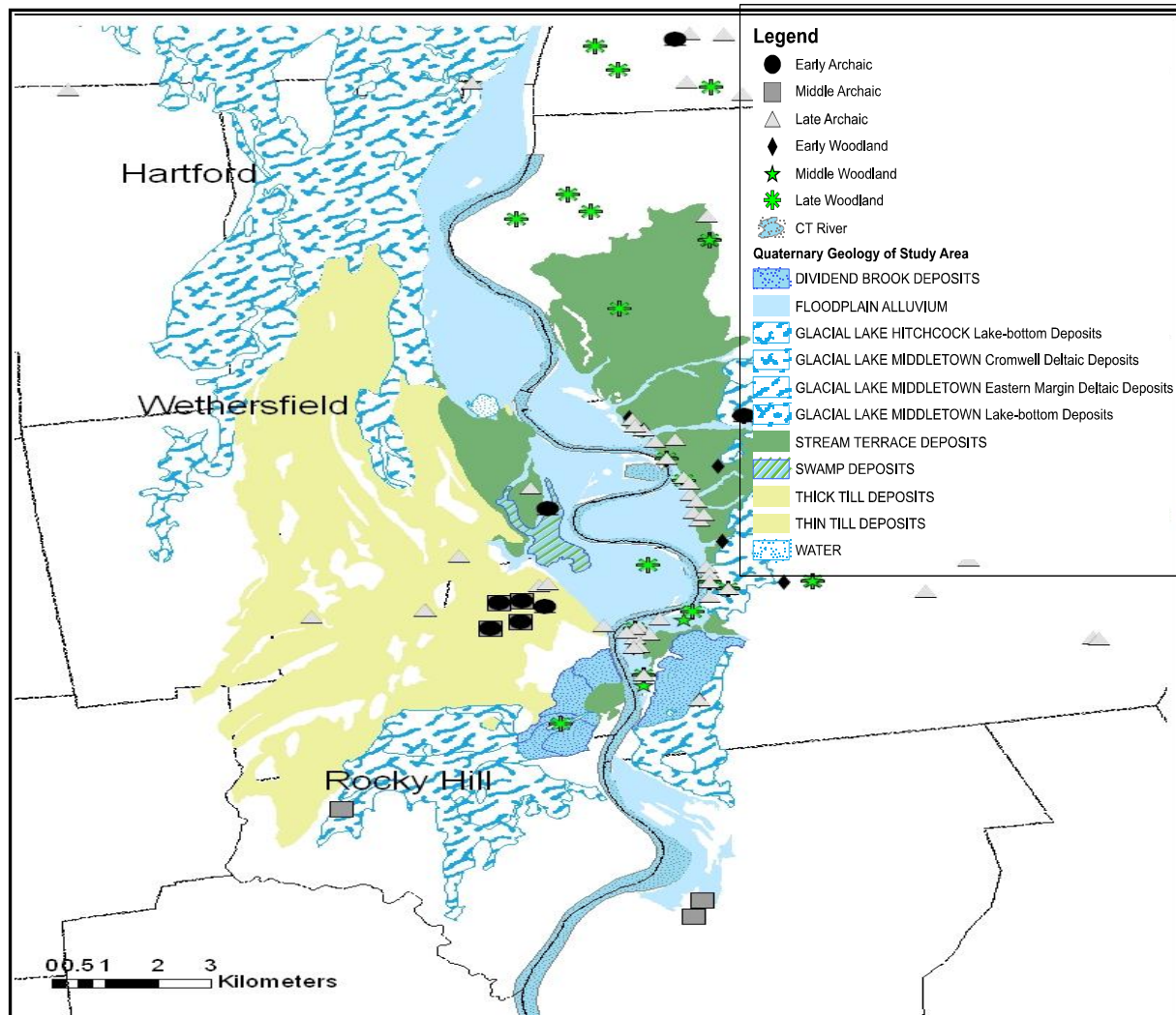


Figure 1.1 The study area. This small segment of the Connecticut River is referred to as the Glastonbury Reach (Forrest et al. 2008; Thorson et al 2014). The numbers 1-6 refer to the floodplain areas in between the meander bends.

“A remnant settlement pattern is the product of at least three kinds of processes: (1) those that control site formation and preservation, reflecting both on-site human activity and the burial and preservation of debris...;(2) those that determine the locational and seasonal features of the sites used during an annual subsistence round and are responsible for some kinds of intersite and interassemblage variability (*short-term processes*)...;(3) those processes that are responsible for year-to-year variability in the geographical positioning and content of assemblages of villages, bases, camps, special-purpose sites, and locations (*medium-term processes*)” (Dewar and McBride 1992: 230).

This remnant settlement pattern analysis uses GIS and sediment analysis to delineate the historic and precontact planforms and planform dynamics to examine the relationship between the archaeological settlement patterns and the meandering river's floodplain landforms. With a more complete geomorphic context provided the cultural processes that contributed to the remnant settlement patterns are investigated.

1.2 Pre-contact Settlement Systems and Alluvial Archaeology

This dissertation research demonstrates that inhabitants of this segment of the Connecticut River Valley utilized the changing meandering alluvial river to organize their settlements systems during the Late Archaic through Woodland Periods. Ethnohistoric accounts and archaeological studies reveal aspects of these settlement systems at the time of contact and the culture history of the Midwest provides a relevant juxtaposition.

The town of Wethersfield, Connecticut was established in 1635, possibly at the invitation of the Wongunks, one of the Connecticut River Indian tribes which had been decimated by small pox in 1633. It has been postulated that the Wongunks only extended the invitation to the English in an effort to keep the encroaching Pequots (also decimated by disease) out of the area or to restore their dominion over the central Connecticut River Valley (Howard 1997; Weider 1986; Ives 2001). The area was called "*Pyquag*" meaning "cleared land". The explorer, John Oldham, reported that the Wethersfield area would be favorable for a settlement due to the presence of cleared fertile soil, on which the Indians cultivated a number of crops. In addition, he noted the presence of an oxbow curve just north of the town, which he believed would make an excellent harbor (Howard 1997; Weider 1986). It soon became clear to the colonists that

much of the cleared meadows were too wet and/or “weedy” to practice their form of agriculture so some meadows were declared common grazing fields for cow herds (Cronon 1983)¹.

In regards to subsistence, the account indicates that Native Americans utilized and cultivated the land in a manner that that could not be duplicated by the English. Current evidence suggests that maize horticulture only supplemented hunting and gathering no earlier than A.D. 1000 (Chilton 2006). Evidence in the Northeast for agriculture is so scant that significant agriculture or any dependence on domesticated crops during the Woodland Period remains debatable (Ceci 1990; Bendremer and Dewar 1992; Demeritt 1991; George 1997; Chilton 1999). However, in the Midwest, which had a seemingly parallel culture history with the Northeast until 2500BP², the beginning of the Midwestern Woodland Period, maize based agriculture (1200BP) was preceded by the production of weedy cultivars in large river valleys around 5000BP (Smith 1992; Smith 1978; Brown and Vierra 1983; Fiedel 2001). During the Woodland Period, populations in the Midwest built monuments, had substantial wars, constructed large ceremonial burial structures, conducted long-distance trade, and developed agricultural food production based on maize and indigenous weedy cultivars (Smith and Cowan 1992). Therefore, the Northeast’s Woodland Period resembles the Midwest’s only by the presence of ceramics, not by dependence on agricultural production.

Based on landscape-scaled geomorphic studies in the Illinois River Valley Mandel (1995) hypothesized that the sediment runoff from the small upland streams into large river valleys, such as the Illinois River, created a larger more productive floodplain that

¹ Cronon(1983) has hypothesized that these introduced-pastoral practices combined with extensive timbering changed increased the stream power of all rivers leading to more frequent and more intense floods which had significant consequences for the landscape.

² All dates uncalibrated

could be exploited by Native Americans sometime between 8000– 4000 years B.P. This increase in the number of archaeological sites in large river valleys was accompanied by a decrease in the number of archaeological sites in the smaller upland river valleys was due to a settlement shift. The settlement shift coincided with the increase in sediment runoff around 8000–4000 years B.P. (Mandel 1995; Ferring 1995). During this time frame, the large river valley sites also increase in size and the cultivation of weedy crops begins, followed by the adoption of maize based agriculture. It is possible that, the increased settlement sizes and/or duration of settlement that began around 8,000 ka in the Midwest may have been the catalyst for the cultivation of weedy cultivars which eventually led to agricultural food production.

Changes in environmental conditions and during the Mid-Holocene in Southern New England apparently did not result in the same sequence of change in settlement and subsistence practices (domestication of indigenous plants and adoption of maize based horticulture) as in the Midwest (Smith and Cowan 1987; Smith 1992a; Smith 1992b; Smith et al. 1992). Local environmental and landscape changes in the Connecticut River Valley played a role in the timing of adaptations and differing cultural responses, although specifics are as yet unclear. In order to demonstrate how the evolution of the local alluvial meandering landscape impacted settlement and subsistence in Connecticut, this dissertation builds upon previous archaeological and geomorphological research in the Connecticut River Valley but focus is at a much smaller scale *i.e.* the reach. By focusing this research at the reach scale the relationship between archaeological sites and the landforms on the alluvial floodplain are identified.

1.3 The Study Area

The Glastonbury Reach study area, herein defined as the segment of the river beginning where the Hockanum River empties into the Connecticut River and ends just north of the Rocky Hill/Cromwell town line is an alluvial meandering reach. It is approximately 10 km long with 2500 ha of floodplain, 2000 ha of terraces, 1600 ha of uplands (Figure 1.1). In this reach the channel is much narrower (180-250m) and deeper (5-10m) than in other reaches. The reach consists of 3 freely moving meanders (6 meander bends³), and is 3km wide at its widest point (Figure 1.2). The meander wavelength maximum is approximately 3,275 m and channel width in this reach ranges from 200-375 m. Since the meander length of the Glastonbury Meadows is about 13 times the width of the river and it has a meander belt that is 10 to 20 times wider than the river itself, with a significantly wider floodplain it is typed as classic meander pattern with moderate sinuosity (MacBroom 1998; Knighton 1998). The present floodplain's landforms consists of a cove with marshes, tidal flats, point bars, channel bars, a broad well developed floodplain with ridge and swale topography, meadows and a beaver pond that is presently, mostly sustained by two stream tributaries, Folly Brook and Goff Brook (Figure 1.2). The floodplains and terraces have been the subject of archaeological survey (avocational and professional) since the mid Twentieth Century. These surveys have uncovered approximately 60 precontact archaeological sites on floodplain and terraces of the study area. An additional 31 sites (Figure 1.2) are located in the study area's stream tributaries and surrounding valley areas.

Since this dissertation concentrates on the floodplain areas the term meander bend which only refers to half of a meander and the floodplain area it contains. Despite changes in meander shape and location the locales are consistently referred to as meander bends 1-6.

The existing archaeological record of the study area provides a necessary foundation for this dissertation's research. The archaeological sites in the Glastonbury Reach are distributed over the floodplain and terraces near coves, marshes, tidal flats, on meadows, and ridges (knolls, as described by archaeologists), in addition to adjacent stream tributaries and quarries (Figure 1.2). The majority of these sites were identified in Glastonbury, Connecticut in a systematic archaeological survey conducted by the Public Archaeology Survey Team in 1979 (McBride 1978; McBride et al. 1980; Dewar and McBride 1992). Although only 190ha of the 610ha of floodplain area were surveyed during the 1979 (Figure 1.2) field season no other town or locale in the study area, or even further upstream, has undergone this level of systematic archaeological survey (Dewar and McBride 1992). However, due to this survey bias, synchronic site counts can provide little information on their own, but can serve as the basis to begin a remnant settlement pattern analysis.

The study area contains sites ranging from the Late Archaic to the Late Woodland Period (Figure 1.2). The majority of sites in the study area have multiple components, but a count reveals: 8 Early Archaic; 4 Middle Archaic; 42 Late Archaic; 15 Terminal Archaic; 14 Early Woodland; 9 Middle Woodland; 12 Late Woodland components. A synchronic count reveals the Late Archaic period site distribution consists of 12 floodplain sites, 19 terrace sites, and 11 tributary sites. The Terminal Archaic record consists of 3 floodplains sites, 5 terrace sites and 7 tributary sites. The Early Woodland record consists of 4 floodplain sites, 6 terrace sites, and 4 tributary sites. The Middle Woodland record for the study area consists of 6 floodplain sites, no sites on the terraces, and 4 sites on the tributaries. Finally, the Late Woodland record consists of 6 floodplain sites, only 1 terrace site, and 6 sites on the tributaries.

Approximate time span	Regional “Period”	Phase
12,000-10,000 B.P.	Paleoindian	—
10,000-8,000 B.P.	Early Archaic	—
8000-7000 B.P.	early Middle Archaic	—
7000-6000B.P.	late Middle Archaic	—
5000-4200 B.P.	Late Archaic	Golet
4200-3500 B.P.	Late Archaic	Tinkham”
3600-2700 B.P.	Terminal Archaic	Salmon Cove
2700-2000B.P.	Early Woodland	Broeder Point
2000-1200 B.P.	Middle Woodland	Roaring Brook
1200-450 B.P.	Late Woodland	Selden Creek
450-300 B.P.	Final Woodland	Niantic

Table 1.1 Lower Connecticut River Valley Pre-contact chronology. Adapted From Dewar and McBride(1992).

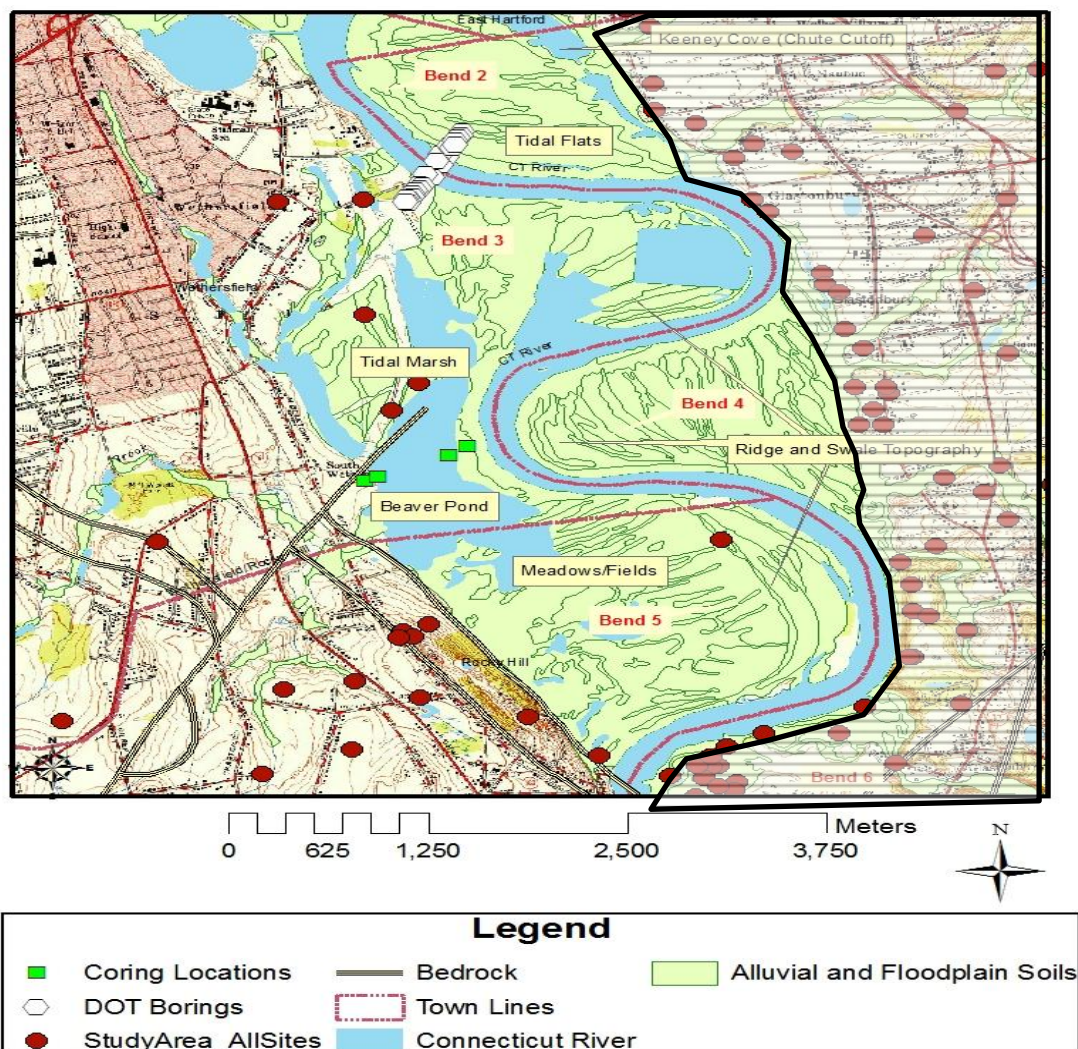


Figure 1.2 Glastonbury Meadows Reach landscape and archaeological site distribution. The shaded areas on east side of channel (Glastonbury, CT) indicate the location of McBride and Dewar’s 1979 survey

The geological studies of the Connecticut River Valley provide a base line for this research (Ridge and Larsen 1990; Patton 1988; Horne and Patton 1992; Thorson 2003; Thorson and Forrest 2008; Thorson et al. 2014; Stone and Ashley 1995; Stone et al. 1998). Current geological studies have revealed that in addition to glacial events, sea level rise and subsequent coastal inundation around 4200 B.P. has been one of the most important factors shaping Connecticut's landscape (Patton and Horne 1992; Koteff et al. 1993). Excessive riverine flooding, possibly caused by a rise in the river's base level (Long Island Sound), resulted in rapid floodplain development as well as flooding, channel meandering and the creation of backwater ponds (Forrest et al. 2008; Thorson et al. 2014). The rapid floodplain development around 6.4 ka would have buried any earlier Archaic period sites that were established on the floodplain or lower terraces during or before the floodplain development stage (Thorson et al. 2014). Around 4200 B.P. coastal inundation is complete and the Lower Connecticut River is submerged and much of it transformed into a tidal estuary (Patton and Horne 1992). The increase in base level and estuary in the Lower Connecticut River valley dramatically slowed water flow out of the Glastonbury Reach leading to a stable meandering regime. Periodically this floodplain would be subjected to flooding by low-energy floodwaters (lake-like) created by back-flooding (Thorson et al. 2014). These floods draped the floodplain with silt and clay deposits but did not result in the destruction of vegetation or archaeological sites (Thorson et al. 2014). However, regular meander adjustments could erode floodplain sites close to the river resulting in a fragmented archaeological site distribution. This established framework, allows for a shift in scale with a focus on the relationship between planform change, landforms, and the settlement patterns of the Late Archaic to the Late Woodland Periods in the Glastonbury Reach.

1.4 Scope of Work

Chapter 2 begins with a review of the archaeological theories regarding precontact settlement and large river valleys. Current thought regarding Pre-contact settlement and subsistence in New England has been summarized in this fashion: Early and early Middle Archaic sites are relatively sparse in the river valleys due to the numerous resources available in wetlands at this time (Nicholas 1987; 1989, 1991; 1998; Handsman 1983). Later Middle Archaic sites are shifting away from wetlands and moving towards the river valleys which may offer exploitable resources due to the number of falls and rapids that may be present (Dincauze 1977; Jones 1999; Forrest et al. 2008). By the Late Archaic Period the subsistence can be characterized as riverine focused (McBride 1984; Dewar and McBride 1992). Moreover, McBride (1984) hypothesized increased use of large river valleys throughout the Woodland Period (3600BP-450BP) with the household becoming the economic unit of production around the Late Woodland/Contact Period. The archaeological site distribution that would support this cultural historical outline would be one with: the majority of Early Archaic sites (9000–8000 B.P.) and early Middle Archaic sites (8000-7000 B.P.) found near wetlands not large river valleys; later Middle Archaic sites (7000–6000 B.P.) will not be near wetlands but, near or in large river valleys and Late Archaic (6000–4000BP) sites will be found on floodplains and terraces of large river valleys with minimal use of the wetlands (Dincauze 1972; Dincauze 1976; McBride and Dewar 1981; McBride 1983; McBride 1984; McBride 1992; Dewar and McBride 1992). However, a preliminary statistical and GIS analysis, presented in Chapter 2, was inconsistent with the expectations. Most significantly, despite the fact that Late Archaic sites were found to

be statistically correlated with large streams, the GIS analysis of the study area could not predict their presence with any greater accuracy than Early or Middle Archaic sites.

Chapter 3 focuses on the timing, connections, and relationships between large scale geological or climatic factors, alluvial processes, landform emergence and culture history in the Glastonbury Meadows Reach. Since, Thorson's et al. (2014) model for Connecticut River demonstrates that during the Late Archaic Period the reach could be characterized as being in a stable floodplain stage (6.4 ka-~2.7 ka). It is postulated that meander migrations that occurred after 2.7 ka are the primary natural process responsible for fragmenting the Late Archaic through Late Woodland archaeological settlement patterns.

Chapter 4 explores the hypothesis that the unexpected results of the preliminary predictive model are the result of the river's historic meander migrations. The known geomorphic history and an examination of 300 years of historic maps are examined to identify rates and patterns of meander migration. The historic planform analysis reveals that historic meander migrations and floodplain development has destroyed the archaeological site distribution in meander bends 1, 2, and 3. However, the channel has not migrated across enough of the floodplain in the last 350 years to have resulted in the current archaeological site distribution in meander bends 4, 5, and 6. Therefore, it is assumed that precontact meander migrations created the archaeological site distribution in the lower meanders. The reconstruction of Pre-contact planform dynamics is necessary to provide a context for the current archaeological site distribution.

Chapter 5 describes the field and laboratory methods utilized to conduct the medium scale research necessary to reconstruct precontact planform dynamics and

their impact on floodplain landforms. The sediments in the cores taken from the floodplain are analyzed using standard sieve tests and the stratigraphy is constructed, presented and compared with borehole data from the construction of the Putnam Bridge, located in the study area. The radiocarbon dates revealed that overbank sedimentation is high and therefore cores, with an average depth of 6m, did not sample beyond 2.7 ka. However, the samples retrieved were useful in partially reconstructing the Pre-contact planforms.

Chapter 6 utilizes the stratigraphic profiles to reconstruct the Precontact planforms. By combining these reconstructions with the results of the historic planform analysis the planform dynamics are also reconstructed. The most likely areas and times of preservation and erosion are delineated and the archaeological site distribution is re-examined. In examining the archaeological record within this context, it is determined that Terminal Archaic, Early Woodland and Middle Woodland archaeological settlement patterns were most affected by the planform changes (3000 B.P. to present). Moreover, it is determined that the archaeological site distribution in meander bend 6 have survived because this meander bend is relatively constrained. Therefore, the settlement patterns within this meander bend are representative of actual Pre-contact settlement (around 4000 B.P.) and the relationship between floodplain ridges and sites on floodplain ridges is explored.

Chapter 7 explores the possibility that the ridge and swale settlement and subsistence adaptation began as early as the Late Archaic Period and may have been a precursor to more permanent settlements and the adoption of agriculture. This chapter examines ethnohistoric and archaeological data to identify the benefits these floodplain landforms offered to precontact inhabitants. To test this ridge and swale landscape

hypothesis additional alluvial river valleys and their archaeological site distributions are also examined.

1.5 Summary

Alluvial environments offer an array of natural resources that has often led to them being considered a major contributing factor when discussing major socio-cultural adaptations and shifts in settlement patterns. By providing reconstructions at a scale relevant to human settlement it is possible to make advances beyond the current anachronistic analyses of eastern North American settlement dynamics.

Alluvial floodplain landforms include channel-edge features such as banks, benches, levees, as well as oxbows, ridges and swales (former point bars or levees), and backswamps. Every floodplain landform can denote an erosional or depositional environment. Therefore, it is necessary to understand the floodplain landform formation processes to infer any constraints or opportunities available to past societies (Brown 1997). In adopting a medium scaled landscape approach that reconstructs the shape and positions of this reach through time this research identifies a relationship between archaeological sites and landforms. This research demonstrates that the development of a stable alluvial meandering regime in the Glastonbury Reach appears to have coincided with a shift in settlement strategies during the Late Archaic through Woodland Periods. It is further hypothesized that the ridge and swale topography, created by the meandering channel, was utilized by precontact inhabitants. It is conceivable that this settlement shift led to an increase in settlement size and/length of settlement and may have been the precursor to maize based horticulture.

Chapter Two: Connecticut's Precontact Archaeological Settlement Patterns

2.1 Introduction

This chapter begins with a brief discussion of the types of settlement models that focus on extensive land use typical of hunters and gatherers and horticulturalists. It then re-examines Archaic and Woodland Period settlement models with a specific focus on the settlement pattern theories that incorporate the Connecticut River and offer testable hypotheses regarding site distributions and environmental context. Finally, this chapter extrapolates on some of the current understandings of the region's settlement patterns and tests some of the current hypotheses by examining the regional site distribution in a GIS. The preliminary statistical analysis and predictive model demonstrates that the current models dominating Pre-contact settlement in New England cannot account for the observable archaeological site distribution in the Glastonbury Reach specifically in regards to Late Archaic site distributions.

In the landscape approach to settlement patterns archaeological sites on alluvial landforms are more than just sites near a river. These alluvial sites had a function and the landforms a site was situated on, or was adjacent to, had a function for that site. Discovery of those functions of place is central to medium scaled remnant settlement pattern analysis. Binford (1982) defines places as spaces of a size and character appropriate for specified functions under a given settlement or mobility strategy. Archaeologists excavating and studying sites in the Connecticut River valley since the 1960s have sought, in various ways, through culture-history construction, comparative archaeology, ethnoarchaeology, geoarchaeology, and remnant settlement pattern analysis to help understand Connecticut's archaeological site distribution. Our current understanding of Connecticut's archaeological site distributions is the result of site

specific investigations and regional surveys. Predictive and explanatory models, as well as large scale (entire rivers or wetland areas) geoarchaeological studies are based on these surveys (Snow 1980; Dincauze 1972, 1974, 1981; Dewar 1986; Dewar and McBride 1992; Forrest 1999; Jones 1999; McBride 1984, McBride 1978; Muholland 1988; Nicholas 1988; Pagouloulatos 1986; Pfeiffer 1986; Thorson and Forrest 2006; Thorson et al. 2014). However, these studies have offered little in the way of understanding settlement patterns at the medium scale, such as a segment of the river valley. Studying archaeological site distributions at this medium scale provides an important context for understanding how the dynamic nature of the hydrological and biotic conditions influenced human responses to the natural environment and the resultant settlement patterns.

2.2 Settlement Pattern Models

Understanding the ecology and geomorphology of the Connecticut River and its influence on Pre-contact subsistence strategies has been a central component in settlement pattern studies in Southern New England. However, smaller scale, more detailed studies of the landscape over time is needed to provide context for Connecticut's evolving archaeological settlement patterns and this has rarely been done, as it has in some river valleys in the American Midwest and Southeast (Butzer 1977, Butzer 1980, 1982; Gardner and Donahue 1985; Waters 1992; Gaffney 1995; Stafford 1995; Goldberg and Macphail 2006). Perhaps, due to the logistical and financial issues of conducting surveys in a compact, densely populated, long-inhabited regions New England archeologists have traditionally preferred a more inductive approach to settlement pattern analysis. Without the possibility of conducting 100% survey in the

state, but with the need to “clear land” for federal and state funded development projects, correlation or predictive models have come into favor.

Predictive models can offer two opportunities to better understand the nature and distribution of archaeological sites: 1) They can identify the natural processes that, in part, formed the current archeological site distribution; 2) They can explain the positive and/or negative correlations in their data. However, despite knowledge that the climate, vegetation, and landscapes of the present, are not the same as those of the past, archaeologists merely identify the correlations between certain environmental variables, and sites but do not explain how the evolution of the landscape may have impacted the settlement patterns. Since these predictive models are usually employed for land management purposes, explanation of any correlations is superfluous. Few predictive models have attempted to address the dynamic nature of the medium scaled hydrological and biotic conditions (e.g. flood cycles, channel shifts) that influence settlement patterns on a year to year, decade to decade or century to century basis.

The models that incorporate such natural transformations often begin with an examination of long term (over millennia) and large scale environmental and landscape change (Forrest et. al 2008; Thorson et al. 2014). Unfortunately, environmental reconstructions at this scale often relegates the landscape as a static backdrop to human land use, and fails to understand the more dynamic aspects of environmental change at smaller scale that often have more dramatic effects on human settlement patterns. These large scale models rely on references to global climatic changes and rely on least common denominators, often ignoring the fact that the impacts of climate change occurs gradually over the course of decades and centuries, with its effects dependent on local (medium –scaled) landscape parameters and human responses to these smaller

scaled changes in the landscape. Regional predictive models that do not treat the landscape as a system constantly in change are employing a reductionist strategy. These reductionist models can offer only general explanations for their correlations and often result in the oversimplification of complex socio-cultural adaptive strategies and dynamic environmental conditions (Allen et al. 1990; Wheatley and Gillings 2002). Archaeologists must treat the landscapes not just as places but as a system of places in constant change (Thorson, personal communication).

In contrast, explanatory models that attempt to address landscape changes are forced to interpret or explain the presence of a site or sites in a particular landscape type (e.g. wetland, alluvial, coastal). Explanatory models of human settlement require the identification of site types integrated with ethnographic analogy within the context of socio-cultural theory and landscape history to understand human settlement across the landscape. Explanatory models, in contrast to predictive models, are more often developed by academic archaeologists who employ settlement system principles and concepts in their analysis, such as focal or generalized economies, annual subsistence rounds or tethered resource procurement strategies (Stafford and Hajic 1992). The typical explanatory model is still a synchronic approach that generalizes hunter-gatherer settlement systems and oversimplifies the archaeological record (Stafford and Hajic 1992). Analysis of Pre-contact settlement patterns requires more than simply matching documented archaeological sites and/or artifacts with settlements in an ethnographic synchronic model of annual subsistence (Dewar and McBride 1992). For example, over the course of a generation or more one “site” was likely occupied dozens of times and perhaps by more than one group. Furthermore, over the course of millennia one environmental locale could have been re-occupied hundreds of times for different

social-subsistence reasons, and in some instances by more than one cultural tradition as has been documented in the Connecticut River Valley (Dewar and McBride 1992; McBride 1984; Pagoloutas 1992). In these cases, simple site counts can be more deleterious to settlement pattern analysis than correlation models because they rarely offer explicitly stated and testable archaeological hypotheses. Therefore, these models shape archeological investigations for decades often resulting in loss of data (Dunnell 1992). For example, it took decades and the discovery of the Neville site Dincauze (1977) to over-turn the Ritchie-Fitting hypothesis that dominated New England Early and Middle Archaic archeology research. Prior to the discovery of the large radio-carbon dated Neville site it was believed that in New England the environment was too harsh to support populations during the Early and Middle Archaic Periods. The size of the Neville Site and the number and variety of artifacts proved, without a doubt, that the New England area was inhabited by hunter-gatherer groups with sophisticated settlement systems. One way of avoiding the pitfalls of site distribution explanatory models is to avoid the use of the traditional site concept (Thomas 1975; Dunnell 1992;) but due to the nature of cultural resource management (CRM), the section 110/106 survey process, and the national register nomination process, the use of the site as the basic unit of analysis is not likely to disappear from American archaeology for some time (Dewar and McBride 1992). Therefore, it is imperative that whenever feasible a landscape approach to settlement pattern analysis should be employed.

Traditionally, settlement models developed to explain site distributions in pre-contact Southern New England have focused on correlating archaeological site distributions with physiographic features and their associated resources using ethnographic types, categorizing Pre-contact populations as either foraging or

residential collectors depending on the immediate and the current surroundings/geomorphic zones (riverine, coastal, wetlands) but, generally have failed to acknowledge the impact of landscape changes, on settlement or the remnant settlement pattern, at a shorter temporal scale and smaller spatial scale (medium scale) (Braun 1974; Brennan 1976; Snow 1980; Muholland 1984; Dincauze and Muholland 1977, Nicholas 1988, Curran and Dincauze 1977; Carlson 1988). The long term and large scale approach coupled with the CRM driven agenda shapes research so that New England archaeology is, for the most part, based on the discovery of an individual site rather than quantitative comparative analysis or the application of new approaches to the study of settlement patterns.

This dissertation which hypothesizes that the inception of a meandering alluvial river and floodplain in the Glastonbury Reach coincided with a statistically significant shift in the Late Archaic through Late Woodland site distributions, examines the natural and cultural record at the medium scale (spatially-the reach-and temporally-over centuries). By adopting a landscape approach at a medium scale for settlement pattern analysis, some of the problems encountered with the use of predictive and explanatory models are overcome.

2.3 Current Archaeological Research and Theory: New England

The Archaic Period (3800-2700 B.P.) in Southern New England has long been interpreted as a transitional stage from foraging to agriculture (Morse, Anderson & Goodyear 1996; Jones 1999; Forrest 1999). Environmental conditions and subsistence adaptations in New England during the Mid-Holocene apparently did not result in the development of indigenous crop agriculture as in the Midwest. In Southern New England Woodland Period sites are marked by the presence of pottery and larger sites

along the Connecticut River with evidence of storage and reoccupation. It is likely that the local environmental and landscape changes in the river valley played a role in the differing cultural responses and rates of change, although specifics are as yet unclear. Since populations respond to changes at the local levels archaeologists must understand local landscape changes to understand the settlement and subsistence responses of hunters and gatherers in Southern New England.

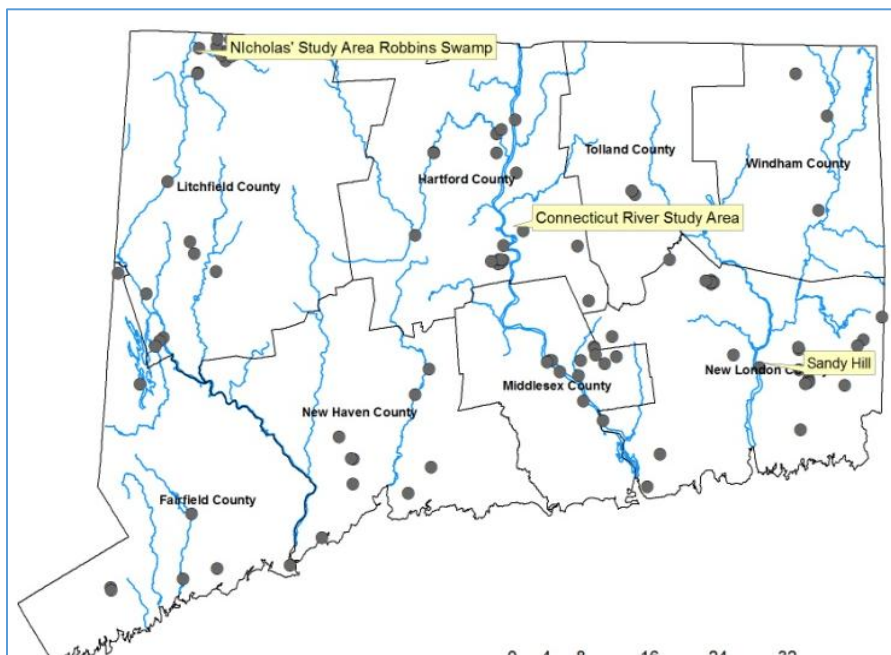
Early Archaic Period (10,000–8,000 B.P.)

George Nicholas (1987) was one of the first archaeologists in Connecticut to adopt a landscape approach to examine the potential influence of Holocene environmental change on human land-use and settlement patterns. Nicholas examined regional trends in settlement patterns and addressed the role of interpretive and preservation biases in reconstructing the settlement patterns of that period. Nicholas (1987) was also one of the first archaeologists to call attention to the need to quantify changes late Pleistocene/early Holocene landforms including alluvial settings. However, his primary focus was on Early Holocene wetland land use in former glacial lake basins, such as Robbins Swamp in northwestern, Connecticut (Figure 2.1). Nicholas (1987) pushed for new avenues of thought, asserting that traditional Early Archaic tyrannies of thought were stifling new research. Prior to the 1980's the Early Archaic was characterized by simple, small populations with a very small archaeological signature. The Early Archaic settlement pattern was characterized as dominated by small sites, a limited number of sites and a narrow range of artifact types representative of a specialized subsistence (Dincauze and Mulholland 1977; Funk 1978; Snow 1980). In an effort to prove that Early Archaic subsistence and settlement was more behaviorally diverse and more adaptive than originally thought, Nicholas argued for the removal of earlier models'

biases by building frameworks that incorporate the landscape perspective (Nicholas 1987).

Two models frame Nicholas' research, a glacial lake basin mosaic model and an ecological leveling model. The glacial lake basin mosaic model is best described as a synchronic explanatory approach to settlement pattern analysis that posits a series of landscape developments. Ecological leveling is a concept used to examine changes in the productivity, and large scale environmental dynamics of former lake basins (Nicholas 1988). The term itself refers to a postulated equalizing between two environmental zones: riverine and wetland. The most effective way to test the validity of the models is to compare and contrast the site distributions in the former glacial lake basin with site distribution in alluvial (non-basin) areas. This type of study would also

Figure 2.1 Early Archaic archaeological sites on record (Connecticut State Archaeology site files 2007).



have to consider changes in the geomorphology of each area at the appropriate temporal and spatial scales. Ironically, Nicholas' argument (1987) for more thoughtfully designed surveys that concentrated on *local*

biases, *local* geomorphic changes and socio-cultural-adaptation through space and time was overshadowed by the successful use of these techniques in wetland resource areas.

The recognition of Early Holocene sites associated with glacial lake basins in northeastern Connecticut coupled with the apparent lack of Early Archaic sites in the Lower Connecticut River Valley (McBride 1984) influenced the adoption of the ecological leveling concept and a shift in excavation venues but not approach, perspective, or theory, until recently. Thorson et al. (2014) model for floodplain stages suggests that the paucity of Early Archaic sites, particularly in the Lower Connecticut River Valley is solely the product of sea level rise and not necessarily settlement choice.

Middle Archaic Period (8,000–6,000BP)

McBride (1984) concluded there was a slight increase in the frequency and diversity of sites for the Middle Archaic Period. Identified sites appeared to be evenly distributed between riverine and upland areas with the majority of the upland sites characterized as temporary camps or task specific locations. No Middle Archaic residential base camps were found adjacent to the Connecticut River. McBride (1984) contends that since there was no evidence of residential base camps in the uplands either, Dincauze's (1976) hypothesis was correct. Dincauze and Muholland (1977) predicted that the majority of Middle Archaic sites would be located in or located on large waterways with falls.

Jones (1999) research of Middle Archaic site types and distributions Mashantucket Pequot Reservation further highlighted the need for more interdisciplinary research in landscapes other than former glacial lake basins. Jones (1999) integrated paleoenvironmental data from extensive geological studies of the Great Cedar Swamp with Middle Archaic site distributions obtained from systematic surveys to argue for a shift in settlement away from the Great Cedar Swamp in the late Middle Archaic Period (7000–6000B.P.). The early Middle Archaic Period (8000–7500B.P.) (represented by Neville and Neville-Variants made of locally available quartz)

is characterized by a relatively high frequency of re-occupied sites indicating predictability in the resource base and stability in settlement. This pattern is in sharp contrast to late Middle Archaic site distributions (represented by the diagnostic of the Stark projectile point) which all but disappear from locales adjacent to the swamp. Jones (1999) hypothesized late Middle Archaic populations shifted their residential base camps to large rivers with falls to exploit shad and salmon runs. Therefore, he predicted that Middle Archaic sites will be found in deeply stratified deposits of the lower Thames, Connecticut and Housatonic River Valleys and locales around former rapids/fall areas that existed at Haddam, East Haddam, and Enfield, Connecticut (Thorson et al. 2014). Unfortunately, the time and cost constraints required to conduct preliminary field reconnaissance and pedestrian survey of the landforms in the river valley precluded any of his suggested research activities.

Late and Terminal Archaic Periods (5,000–2700B.P.)

Dewar and McBride's (1992) landscape approach to reconstruct the archaeological site distribution in the central Connecticut River Valley in Glastonbury, which includes a portion of this dissertation's study area, highlights the complexity of Late to Terminal Archaic hunter-gatherer settlement patterns. Systematic surveys were conducting using a stratified random sample of four major landscapes: the floodplain, terraces, uplands and the floodplain of a major upland stream located 56 Late and Terminal Archaic archaeological sites of various sizes and occupation characteristics. Their research emphasized the effects of medium-term processes brought about by cultural activities such as (refuse disposal, firewood depletion, etc.) on site occupation length and potential for reoccupation (temporal continuity and spatial congruence). Survey results document the presence of very large (>8500m²) Late Archaic Tinkham Phase (4200–

2900 B.P.) sites on the floodplain of the Connecticut River Valley, described as re-occupied base camps (Figure 2.2). These sites are always located on what are described as low rises on the floodplain with all of the sites measuring less than 10m wide and hundreds of meters long and always limited to the ridges (Dewar and McBride 1992; McBride 1978). Dewar, McBride, and others (Cooke 1988; Lavin 1988) who located sites on these floodplain ridges referred to these low rises as “knolls”. These “knolls” are described as long linear ridges, slightly elevated above the floodplain (Rignall 1977; Cooke 1988; Lavin 1988; McBride 1978; Feder 2001). In addition, to these large ridge sites, many medium sized sites (1500–7500m²) were located on the terraces adjacent the floodplain, but only small single occupation sites (250m²) were identified in the uplands of the river valley. This distribution indicated that reoccupation of floodplain ridges and terraces, during this phase was common, and that these landforms were preferred locales for settlement. Tinkham Phase floodplain sites are the result of a long, localized sequence of occupation with high temporal continuity and moderate spatial congruence. Overlapping archaeological features, botanical and faunal data indicates residential base camp of several families with summer and fall occupation of the floodplain suggesting that winter/spring occupations by nuclear families characterized the smaller sites in the terraces.

In contrast, the archaeological record associated with the Terminal Archaic Salmon Cove Phase (3600–2700 B.P.) shows limited continuity or congruence of settlements on the floodplain or terraces (Figure 2.3). Any Salmon Cove Phase sites located on the floodplain or the terraces are all very small. None of the terrace zone sites have concentrated occupation sequences and all are located predominantly on the western edge of the terrace, overlooking the floodplains. Furthermore, no Salmon Cove

Phase sites were identified in the uplands. Since the sites are on the low terrace the setting had the advantage of receiving floodwaters but remained clear of the destructive effects of the migrating channel. Thorson and Tryon (2003) highlight the benefits situating sites on terraces as well as the preservational advantages of these landforms. However, the limited cultural activity on the floodplain and in the upland areas indicated either year-round occupation of the terraces, (with more terrace sites yet to be discovered) or terrace occupation along with the occupation of another, zone not covered in the 1979 survey, or both. Another possibility is that channel shifts destroyed evidence of residential Terminal Archaic Salmon Cove Phase sites on the floodplain. It is possible that terrace sites were only used during high/large floods, which mostly occurred in the spring (Dewar and McBride 1992; Thorson personal communication). Based on the higher number of terrace sites Dewar and McBride (1992) hypothesized a riverine economy dependent upon the shad and/or salmon runs of early spring.

Incorporating alluvial geomorphology to Dewar and McBride's remnant pattern analysis could clarify and/or reinforce some of their conclusions. For example, it is possible that the Salmon Cove Phase settlement pattern "shift" on the floodplain and terraces is the result of meander migrations that either caused a shift in settlement or resulted in fragmentation of the archaeological record. Appropriately scaled geoarchaeological research shall provide a much needed context for the Late and Terminal Archaic settlement systems on the floodplain. Currently, it is still unknown whether the substantial shift in settlement patterns from Tinkham Phase to the Salmon Cove Phase signaled the influx of a new society or if it signaled a change in the local landscape and/or environment that forced people to modify their settlement choices. Certainly, neither hypothesis can be ruled out at this time.

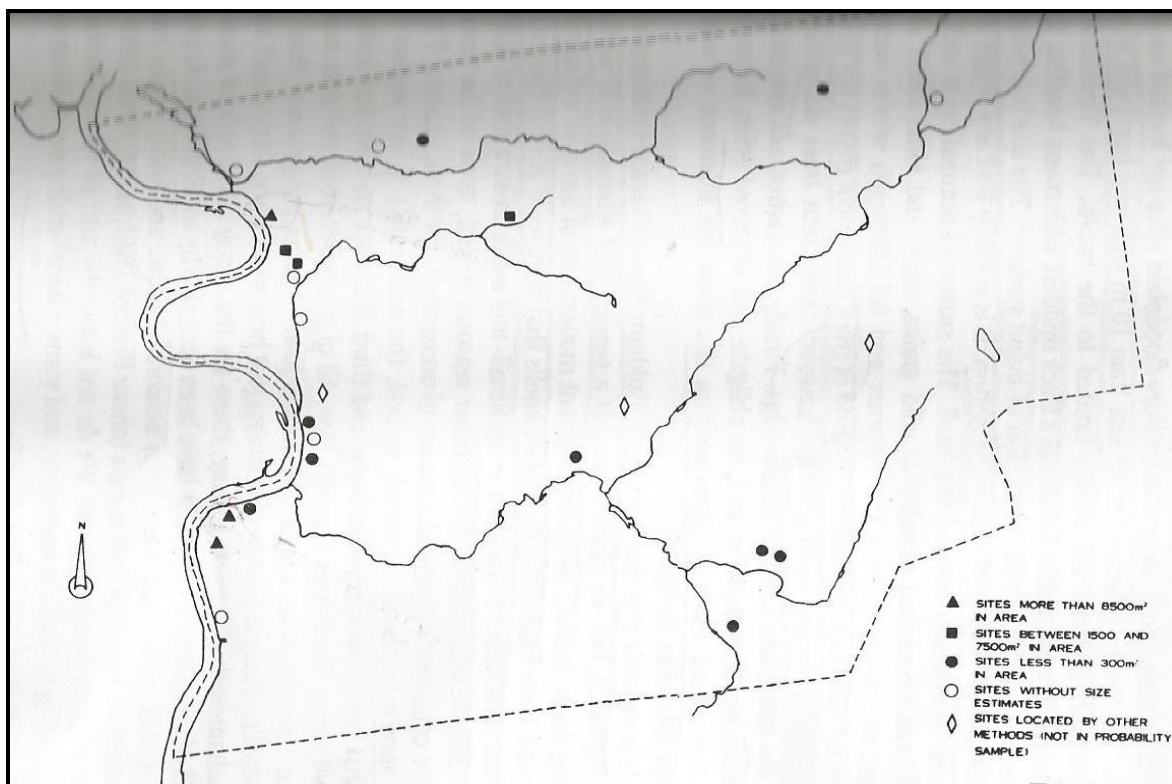


Figure 2.2 Late Archaic Tinkham Phase components in Glastonbury (Image from Dewar and McBride 1992).

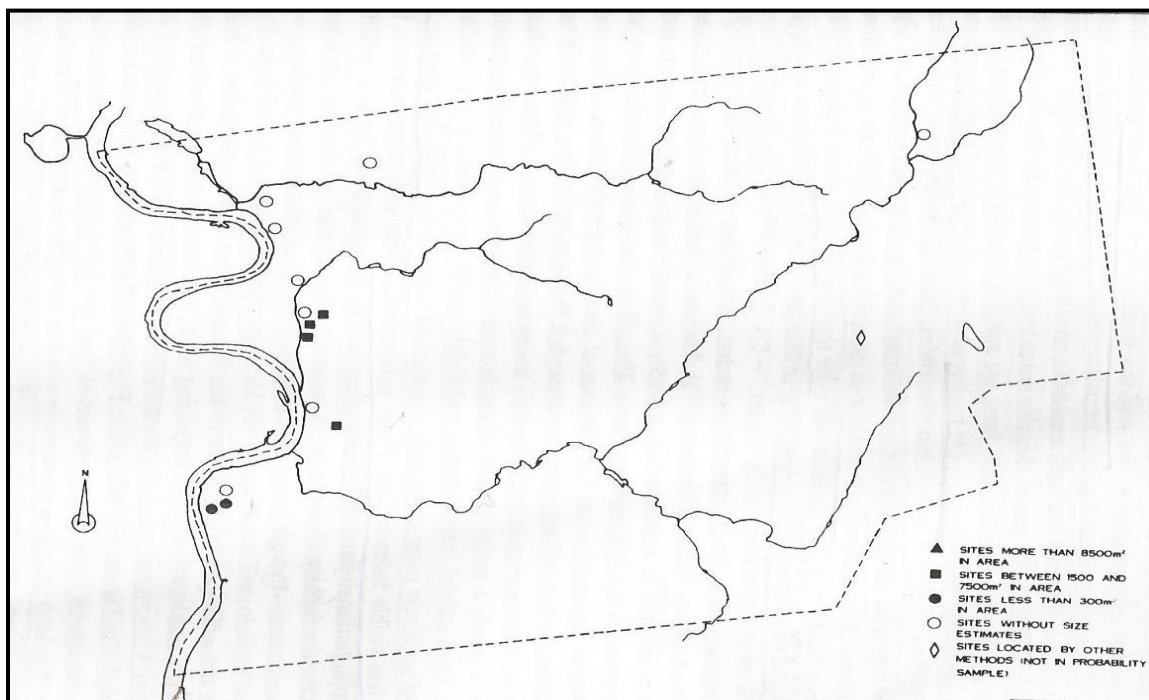


Figure 2.3 Terminal Archaic Salmon Cove Phase components in Glastonbury (Image from McBride and Dewar 1992)

Early and Middle Woodland Period (2700–1200 B.P.)

McBride's (1984) archaeological study is the most comprehensive settlement pattern analysis of Early Woodland to Contact Period site distributions in the Lower Connecticut River Valley. The Early Woodland Period's Broeder Point Phase (2700–2000 B.P.) is defined as a return to the type of collector strategy identified in the Tinkham Phase of the Late Archaic Period (McBride 1984). Unfortunately, a limited number of Early Woodland sites were identified so this conclusion is tentative. McBride (1984) documented another settlement pattern change during the subsequent Roaring Brook Phase (2000–1200 B.P.) of the Middle Woodland Period. This phase is characterized by increased occupational focus along the river with temporary and task specific sites located in the uplands of the Connecticut River Valley. The sites present are mostly seasonal and task specific camps, characteristic of logistical organization. However, the Roaring Brook Phase differs from Salmon Cove Phase of the Late Archaic in that the Roaring Brook Phase, upland sites are larger and seem to reflect much longer periods of use. In addition, the task specific sites show an increase in the use of “exotic” Mid-Atlantic lithic material indicative of another settlement adaptation (McBride and Dewar 1987).

The Middle Woodland settlement pattern is also characterized by fewer residential sites indicating population aggregation into fewer and larger sites within a more circumscribed area (Bragdon 1996). It is possible that the Connecticut River's winter/spring flooding influenced the settlement/subsistence round of this period. The research of Thorson et al. (2014) shows that at this time the floodplain was relatively stable but that there were long periods of little to no activity punctuated with high energy, volatile floods (Thorson et al 2014). However, no large seasonal camps were

identified in the uplands after AD 600 but, these areas were still being exploited, as evidenced by the increase in special purpose task camps.

Late Woodland and Contact Period (1200–300 B.P.)

Late Woodland patterns are quite different than the Final Woodland/Contact patterns established in the ethnohistoric record. During the Late Woodland Period there is a significant settlement shift that places focus on small fall-winter seasonal camps suggesting that by the Final Woodland Period the household, not the village, is the economic unit of production (McBride 1984). The Late Woodland Selden Creek phase (1200–450 BP) is a continuation of Roaring Brook Phase with increased aggregation, reflected by increased site size and reduction in overall site counts on the river, intensified exploitation of the uplands, and a substantial increase the use of imported raw material. The archaeological record shows variability in tool assemblages indicating more and varied site activities at the riverine village sites.

By the Contact Period (450–250 BP) task specific upland camps are replaced by small seasonal camps that McBride (1984) interpreted as family residences. Villages continue to be located along the river and some of the small spring/summer camps in the river valleys of the uplands are interpreted as small family units in the vicinity of dispersed agricultural fields. There appears to be at least two economies one that exploits the coastal margins and another that utilizes the interior riverine systems. It is unclear if these are the economies of multiple societies or if there is one occupying the coast and the other the interior riverine systems.

The ethnohistoric and archaeological record suggests that in Connecticut, large villages along the river were occupied in the summer and fall months (McBride 1984). However, the ethnohistoric record associated with the Narragansett of coastal Rhode

Island suggests that the winter months were spent exploiting interior riverine ecological systems through hunting and gathering while spring occupations were located along the coast adjacent to planting fields (Pagaloutas 1990). Certainly, at this point in history it is likely there were multiple settlement strategies being used by multiple groups. It is important to note that this final settlement pattern shift to a household focal economy did not occur until AD 1500, some 500 years after the adoption of maize horticulture and well after the incorporation of weedy cultivars which is believed to have begun in the Terminal Archaic Period (Pagaloutas 1990). Therefore sedentism, ceramic technology and/or villages are not the consequences of agricultural economies but rather agriculture may be the product of a successful riverine centered food forest economy (McBride 1978; McBride and Dewar 1987).

2.4 Archaeological Site Distribution Analysis

The glacial lake basin ecological leveling model is the currently accepted explanation of the Archaic Period site distributions. This glacial lake basin ecological leveling model is based on the postulate that wetland-dominated mosaics extremely rich in resource diversity existed within many of the former glacial lake basins. It is postulated that these wetland mosaics were the focal point for Early Archaic and early Middle Archaic settlement because the coastal plain was too affected by transgressing sea levels and the newly forming river valleys did not offer stable predictable resources. This biotically rich and diverse geomorphic zone meant a collector settlement strategy was employed around the wetlands. It is further hypothesized that environmental fluctuations that caused the wetlands to decline in resources, simultaneously caused large river valleys to increase in productivity, thereby resulting in a corresponding shift in settlement strategies (Nicholas 1987, 1988, 1991, 1998; Jones and Forrest 2003). Accordingly this

model predicts that the majority of Early Archaic sites (9000–8000 B.P.) and early Middle Archaic sites (8000–7000 B.P.) will be located near wetlands not river valleys; later Middle Archaic sites (7000–6000 B.P.) will be rarely associated with wetlands but near or in large river valleys; and Late Archaic (6000–4000BP) sites will be found on floodplains and terraces of large river valleys with minimal use of the wetlands (Dincauze 1972; Dincauze 1976; McBride and Dewar 1981; McBride 1983; McBride 1984; McBride 1992; Dewar and McBride 1992). Since the regional archeological dataset for the Woodland Period is larger and more difficult to interpret due to the likelihood of several distinct socio-cultural groups that inhabited the Connecticut Valley at the time of contact, the Woodland settlement pattern analysis focuses solely on site distributions in large river valleys and the utilization of alluvial landforms and resources. Therefore, the Woodland Period settlement patterns can only be discussed after the landscape analysis.

Archaic Period Settlement Pattern Analysis

The models outlined above (Nicholas 1987, Jones 1999, Dewar and McBride 1992) hypothesize settlement adaptations to particular landscapes such as wetlands, river valleys, terraces in response to changes in large scale environmental and/or social changes. A geographic information system (GIS) was used to qualitatively determine if sites of a certain time period correlate with selected environmental variables. A sample of 543 Archaic Period sites was selected from each of Connecticut's major ecoregions (western uplands, central river valley, coast, eastern uplands). The biophysical factors thought to be associated with the presence of sites are: distance to small streams, distance to large streams, distance to glacial wetlands, soil type, elevation, slope, and aspect, were tested for significance. The absence of non-site environmental data

prohibited a logistic regression (Kvamme 1989; Kvamme et al. 1988; Warren 1990; Gaffney and Leusen 1995) but differences in Early, Middle, and Late Archaic sites were examined using chi-square analysis (Tables 2.1-2.3). The variables found to be significant were distance to water, wetlands, sandy and gravelly soils and gradual slope. Linear regression revealed the following correlations: (1) Middle Archaic sites are more likely to be located closer to wetlands than Early Archaic or Late Archaic sites; (2) There is a significant trend for sites to move closer to major streams over time with Early Archaic sites being negatively correlated with large streams and weakly correlated with small perennial streams; (3) Late Archaic sites are positively correlated with large streams. This analysis does not provide any explanation for the correlations it merely shows that a correlation exists. However, it should be remembered, particularly, when looking at the Early and Middle Archaic site distributions, that survey bias is high. Additionally, the Middle Archaic sites were not separated into early or late Middle Archaic sites. Nevertheless, the analysis does permit us to refocus on the predictions of the settlement pattern theories.

Distance to Wetlands	Early Archaic Sites	Middle Archaic Sites	Late Archaic Sites	TOTAL Number of Sites
0 – 91 meters	10	22	46	78
> 91 meters	66	82	307	455
TOTALS	76	104	353	533
Standard Deviations				
0 – 91 meters	0.336	1.738	-0.787	
> 91 meters	0.139	-0.720	0.326	
Pearson chi-square	Value 4.397	df 2.00	Probability 0.11	

Table 2.1 Frequencies of archaeological sites near wetlands

Distance to Small Streams	Early Archaic Sites	Middle Archaic Sites	Late Archaic Sites	TOTAL Number of Sites
0 – 152 meters	53	69	233	355
>152 meters	23	35	120	178
<i>TOTALS</i>	<i>76</i>	<i>104</i>	<i>353</i>	533
Standard Deviations				
0 – 91 meters	0.335	-0.032	-0.138	
> 91 meters	-0.473	-0.046	0.195	
Pearson chi-square	Value .395		df 2.00	Probability 0.821

Table 2.2 Frequencies of archeological sites near major streams

Distance to Major Stream	Early Archaic Sites	Middle Archaic Sites	Late Archaic Sites	TOTAL Number of Sites
0 – 152 meters	3	11	50	64
> 152 meters	73	93	303	469
<i>TOTALS</i>	<i>76</i>	<i>104</i>	<i>353</i>	533
Standard Deviations				
0 – 152 meters	-2.028	-0.421	1.169	
> 152 meters	0.749	0.156	-0.432	
Pearson chi-square	Value 6.429		df 2.00	Probability 0.040

Table 2.3 Frequencies of archaeological sites near small streams

When the biophysical variables were layered over each other to create a predictive map in the study area an additional anomaly was found: Late Archaic sites, which should have less survey bias, were predicted with less accuracy than Early Archaic sites. To create the predictive map areas up to 300m away from major streams, minor streams, and 45 to 100 meters from the boundaries of glacial lake basin wetlands, with a slope between 0 and 12% and a sandy or gravelly soil are coded as “High” sensitivity with respect to site locations. Areas with a sandy or gravelly loam soil, with a slope between 0 and 12% slope, and 300 meters from a stream are coded as “Medium” sensitivity with respect to site locations.

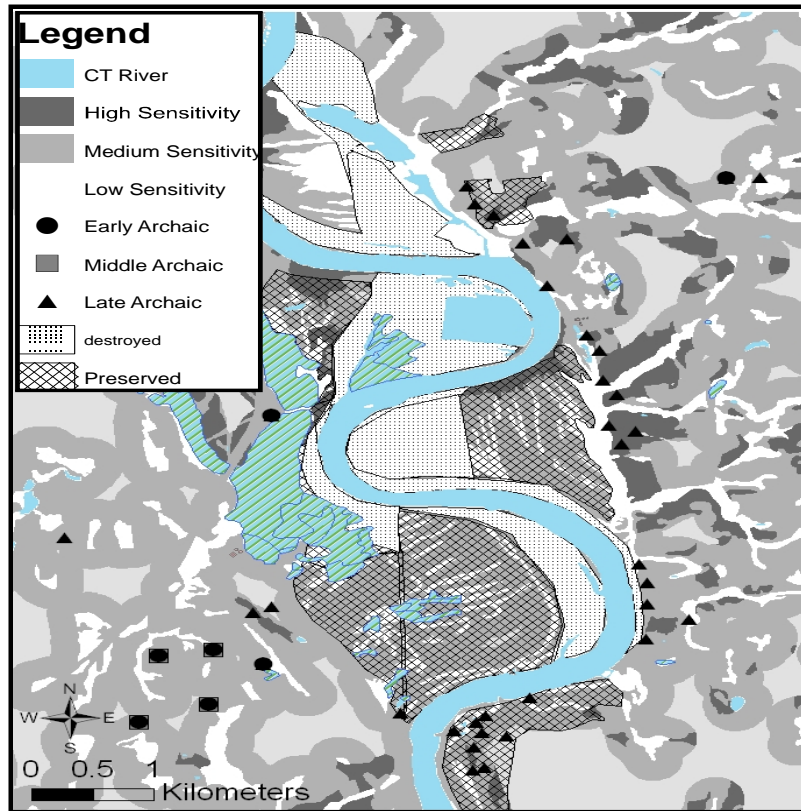


Figure 2.4 The sensitivity map that shows archaeological sites , particularly Late Archaic sites, are in “high correlation environments” even when accounting for historic meander migrations

Areas with a without any of the tested biophysical variables are labeled “Low” sensitivity (Figure 2.4). Areas that fell within the migration path of the river as indicated by historic maps (1636-1935) were marked as destroyed.

Forty-seven sites that were not used in the chi square analysis were placed in the sensitivity map to test the predictive power of the map.

The map predicted 95% of

Early Archaic sites, 77% of Middle Archaic sites, but only 86% of Late Archaic sites came up in the areas marked as “Highly Sensitive”. The map’s predictive power for the Early Archaic indicates the following 1) perennial streams need to be examined more closely than wetlands for the Early Archaic Period sites⁴ ; 2) The site Late Archaic Period site distribution in the study area is more complex than originally thought. Although a high percentage of Late Archaic sites were predicted, more sites fell farther away from the streams than expected. Thereby indicating that in the study area there are either sites

⁴ In Connecticut, wetlands classification is based on soil characteristics. Thorson (personal communication) more detailed wetland classification needs to be done b archaeologists in order to examine the validity of the Nicholas’ near wetland hypothesis.

yet to be discovered, sites are destroyed and/or the Connecticut River is not where it used to be.

Geoarchaeological investigations are necessary to explain these results and assess whether these remnant settlement patterns represent changing settlement preferences or are merely products of archaeological survey bias and/or planform dynamics. The questions that need to be answered for archaeologists to engage in meaningful settlement pattern analysis are:

- has the Connecticut River planform changed through time? When did these changes occur?
- How has Connecticut's changing alluvial landscape been settled and utilized?
- Which alluvial settings are likely to have been deliberately selected by Archaic Period populations and which are more likely to be preserved?
- Are gaps in the archaeological record caused by erosion of sediment, massive sediment deposition, or a real absence of habitation?
- Does the location of early Late Archaic sites in large river valleys indicate a major subsistence shift?
- Did Terminal Archaic, particularly the Salmon Cove populations (6000–3700BP) prefer residence near rivers rather than near the wetlands, that were restored by 5000BP, or is this an artifact of river migrations?
- Did Woodland Period populations begin a shift to a more sedentary society and then maize agriculture as a result of the development of a stable river.
- When did floodplain and terraces develop?
- When did the floodplains and terraces become habitable for semi-permanent populations?
- Which areas are likely to have been deliberately selected by Archaic and Woodland Period populations and which more likely to be preserved?

2.5 Summary and Conclusion

Past local environmental conditions are poorly documented but it has become standard practice to assume that the known global environmental events and climatic shifts can be applied to the local environment without critique. The current understanding of Connecticut's Pre-contact site distributions is the product of a variety of early predictive, explanatory and landscape approaches to the archaeological record (Snow 1980; Dincauze 1972, 1975, 1981; Dewar 1986; Dewar and McBride 1992; Forrest 1999; Jones 1999, 2009; McBride 1984, McBride 1984b; McBride and Dewar 1991; McBride 1978; Muholland 1988; Nicholas 1982, 1983, 1984; Pagouloulatos 1986; Pfeiffer 1985). Most approaches focus on 3 ecozones: upland wetlands, inland rivers, and coastal estuaries

and marshes. Accordingly, these models predict that the majority of Early Archaic sites (9000–8000BP) will be found near wetlands not large river valleys; later Middle Archaic sites (7000–6000BP) will not be near wetlands but near or in large river valleys and Late Archaic (6000–4000BP) sites will be found on floodplains and terraces of large river valleys (Dincauze 1972; Dincauze 1976; McBride and Dewar 1981; McBride 1983; McBride 1984; McBride 1992; Dewar and McBride 1992).

Statistical analysis and mapping raised questions about the current theories regarding Early, Middle and Late Archaic Periods. Although new research (Thorson et. al 2014) demonstrates that the lack of Middle Archaic sites in large streams is likely a preservation issue, this statistical analysis raised questions regarding the Late Archaic site distribution and the factors that created it. Delineating the planforms and the alluvial landscape of the Glastonbury Reach study area for this time period and subsequent periods may be crucial to understanding this significant shift in settlement to a riverine focused economy (Dewar and McBride 1992). More detailed work regarding the historic and precontact planform changes needs to be done to determine how the Late Archaic through Woodland archaeological site distributions have been impacted.

Chapter Three

The Alluvial Landscape: A History of the Connecticut River

3.1 Introduction

An understanding of the landscape, its evolution, its impact on human settlement and its fragmentation of the human record is an essential first step to reconstruct various aspects of settlement and subsistence within the context of remnant settlement pattern analysis. Large scale environmental backdrops can only serve as a base from which archaeologists must conduct more appropriately scaled research. Appropriately scaled, research of an alluvial river is limited to the reach. Understanding when, why and how streams transports, erode, and deposit sediment is necessary to understand archaeological settlement patterns in that reach (Goldberg and Macphail 2006).

However, it is first necessary to understand some fundamentals regarding the alluvial processes and the landforms created or eroded. This chapter examines the alluvial river and landscape at a large scale as well as the local level. It is not meant to be a detailed study of the geology, hydrology, or fluvial geomorphology of the Connecticut River. Rather, it focuses on the timing, connections, and relationships between large scale events and local geological constraints and alluvial controls operating in a single reach, the Glastonbury Reach, in the Connecticut River Valley. By far the most important factors framing the physiography of the Connecticut River valley are glacial retreat, climate change and sea level change. Yet, it is the variation in the smaller variables of slope, water flow rate, and sediment load and transport operating within this broader framework that really formed and changed the alluvial landscape. All of the factors are examined together to establish the parameters that can be used to constrain and shape ideas in regards to how the river's dynamics impacted the remnant settlement pattern.

Therefore, emphasis is placed on identifying the processes and delineating alluvial landforms at a scale that is relevant to human settlement and geoarchaeological investigation (Guccione et al. 1998; Goldberg and Macphail 2006). This chapter begins with a brief description of the present day Connecticut River Valley and the physical landforms and bedforms that can comprise the alluvial landscape. A brief geomorphic history of the Connecticut River with a focus on floodplain formation and meander development follows.

3.2 Physical Geography

The Connecticut River is a 650 km alluvial stream that begins in New Hampshire and empties into Long Island Sound (Figure 3.1). It is the longest river in New England flowing through Vermont, New Hampshire, Massachusetts and Connecticut. The Connecticut River is a tidal stream, in Connecticut only, and although the mixing of salt water and freshwater only extends 20 km north of Long Island Sound, tidal influence is found all way into Enfield, Connecticut, approximately 100 km north of the Sound. Due to the bedrock geology, glacial capping, glacial lake formation and emptying, the Connecticut River can be broken up into many segments or reaches. Each reach is characterized by a certain set of variables such as, the presence of falls, floodplains, and meanders. Thorson et al. (2014) identified an approximate 125 km² area as the Connecticut River Alluvial Lowland (CRAL). The study area of this dissertation falls within the CRAL, along with other distinct segments (reaches). The CRAL can be defined as the channel, floodplain, postglacial fluvial terraces that fall between two bedrock pinch points, in Enfield, Connecticut and in Rocky Hill, Connecticut. Since the focus of this dissertation is change in river alignment and channel location, this dissertation combines the Rocky Hill and Glastonbury reaches which were identified as

two distinct reaches in Thorson et al. 2014. The other segments of the CRAL are the: Enfield Reach, Windsor Reach, Hartford Reach, and the Cromwell Reach. The Enfield Reach begins in northern Connecticut and extends approximately 7km south. This reach is essentially bedrock- controlled (Portland-Formation) and characterized by rocky waterfalls (Thorson et al. 2014). In this reach the channel is relatively straight and largely kept in place by resistant glacial till. Here, the river is shallow (1–50m) and wide (300–365m) with low steep banks. These banks are stable and not subject to erosion especially where vegetation is present. This lack of channel erosion means that the stream cannot easily adjust its size or course and there is little sediment available for large floodplain formation. At the end of the Enfield Reach the river drops approximately 20 feet creating the “Enfield Falls” and the Windsor Reach follows. The Windsor Reach stretches from Windsor, Connecticut to Hartford, Connecticut a distance of 14km. Presently, this reach has a straight morphology and flows on a 2 km wide floodplain. However, the floodplain shows signs that the channel may have once meandered across the floodplain.

In the most northern portion of the next reach, the Hartford Reach, bedrock constrains channel movement (Thorson et al. 2014). The reach is very and narrow (155 m) and deep (8.5 m). It has two fast flowing tributaries emptying into it: The Park River a meandering stream enters the Connecticut River from the west (Hartford); and the Hockanum River which enters from the east (East Hartford). The fast flowing Hockanum River and its alluvial fan serve as another constraint to migration in this reach (Thorson et al. 2014). The bedrock, alluvial fans, and erosion resistant terraces have all served to constrain movement in this reach, therefore it has a very narrow floodplain.

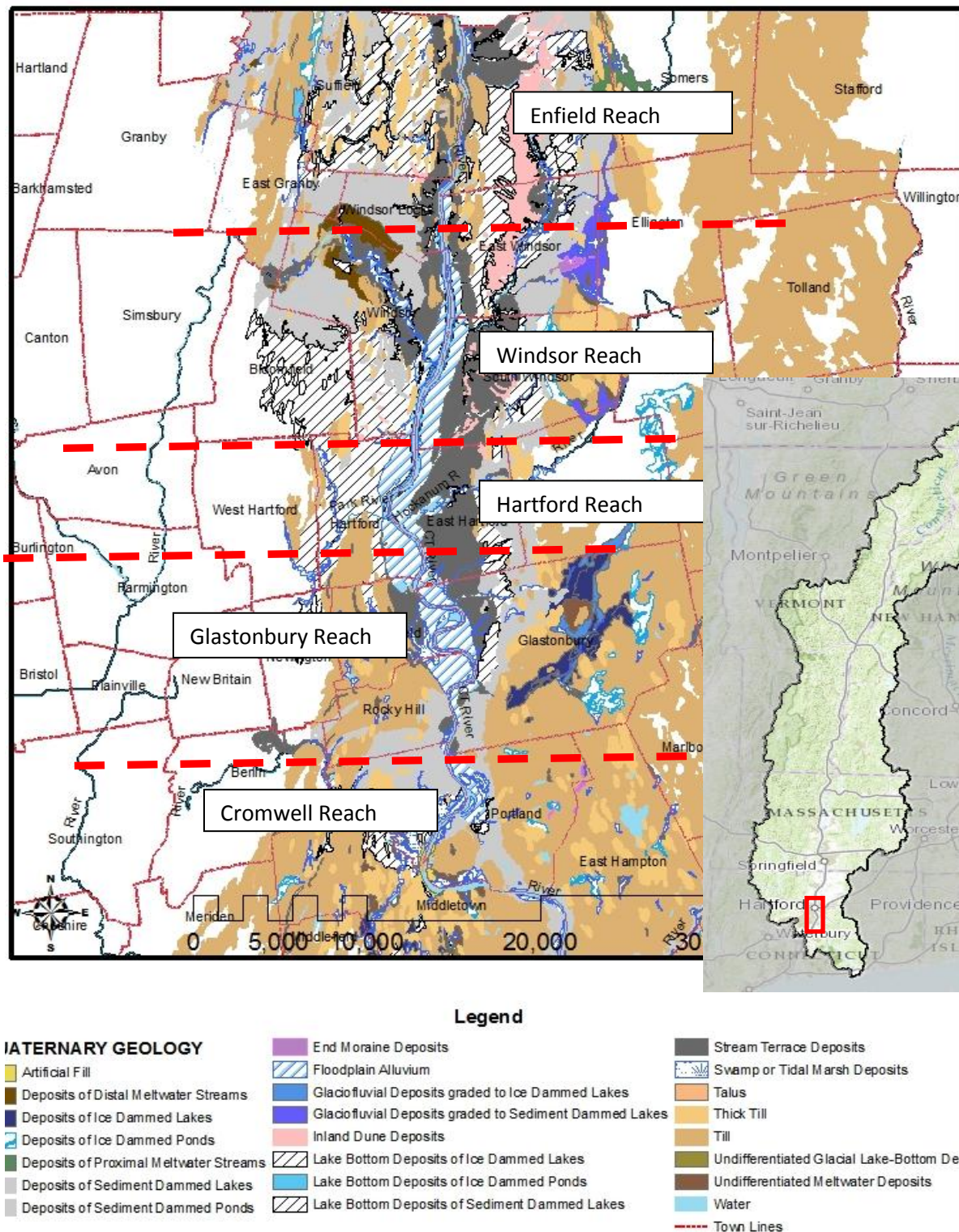


Figure 3.1 Connecticut River Valley with the reaches of the CRAL identified.

Farther downstream, is the Glastonbury Reach, the majority of reach is not constrained by bedrock or resistant sediments (currently man-made levees, non-erodible linings, and other features serve as constraints).

The Glastonbury Reach is here defined as the segment of the river beginning just south of where the Hockanum River empties into the Connecticut River and ending just north of a bedrock ridge. It is approximately 8 km in length and consists of 6 meander bends⁵. Its floodplain is only 3 km wide at its widest point, but the channel is also very wide (200–350 m) and deep (10–15 m) (OceanGraphix Chart 12378). This alluvial meandering reach is primarily composed of easily erodible glacial till and fine grained lacustrine sediment underlain by arkose sedimentary rock (MacBroom 1998). The average meander wavelength maximum⁶ in the Glastonbury Reach is approximately 4 km (Thorson et al. 2014). It is classified as a classic meander pattern with moderate sinuosity (MacBroom 1988, Knighton 1998). The present floodplain's landscape elements consist of a cove with marshes, tidal flats, point bars, channel bars and a broad well developed floodplain with point bars, levees, and ridge and swale topography (Figure 3.2). The floodplain landforms are identifiable by their shape, position in relation to the channel, surficial soil, and stratigraphic profiles. For example, abandoned channels like Keeney Cove, the former main channel of the 17th century Connecticut River, appear as linear depressions on the floodplain, often asymmetric, with either straight or curved depressions. Since Keeney Cove is still connected to the main channel it can also be classified as a cove. If it did not connect back to the river it

⁵ Due to this dissertation's focus on the floodplain and floodplain archaeological sites an unconventional approach to discussing meanders was adopted. The normal geologic convention enumerates meanders by measuring one full wavelength from node to node. This conventional approach would result in 3 meanders and 6 meander bends –half of a full meander (from East Hartford, CT to Rocky Hill, CT).

⁶ Meander wavelength: The distance of one meander along the down-valley axis.

would be considered an oxbow lake. Presently, Keeney Cove has a marsh ecology which offers, a calm environment ideal for spawning fish, birds, and other wildlife. Ridge and swale topography appears in bends 3, 4, 5, and 6 (Figure 3.2). In planform the scroll bars (ridge and swale topography) are curved bars composed of Limerick/Lim and Hadley Silt Loam soils indicating a laterally migrating channel in the past. New floodplain deposits (point bars and levees), immediately adjacent the channel, are primarily composed of Pootatuck Fine Sandy Loam or Occum fine sandy loam. Other alluvial landforms, in the reach, that owe their existence to the meander migrations and evolution of the Connecticut River include Cove Point, in Wethersfield, and a beaver pond on the west bank of the river. Terraces, thick glacial deposits and an exposed bedrock ridge, at the southern most point of the reach prevent some of the meanders from moving freely across the floodplain (Bell 1985; Stone et al. 2005).

3.3 Geomorphology of the Glastonbury Reach

Presently, the Glastonbury Reach is characterized as a stable reach with silt and sand banks, low regional slope, and low regional slope. Average flow velocity for the reach is .60 m per second Ostfeld (2011: 22). Stable transverse bars in the area range in height from <.0.5 to 1.75 m in height. Ripples, dunes, and vegetation on two of these bedforms indicate that regular water flow has low to moderate velocity. The relatively low flow and presence very coarse sand inhibit bedform evolution under normal conditions (Ostfeld 2011:93). Periods of high discharge or flood events are required for bedform movement. These conditions indicate that in this reach, any major disturbance in slope, flow, sediment supply, or stream power could take hundreds of years to mitigate.

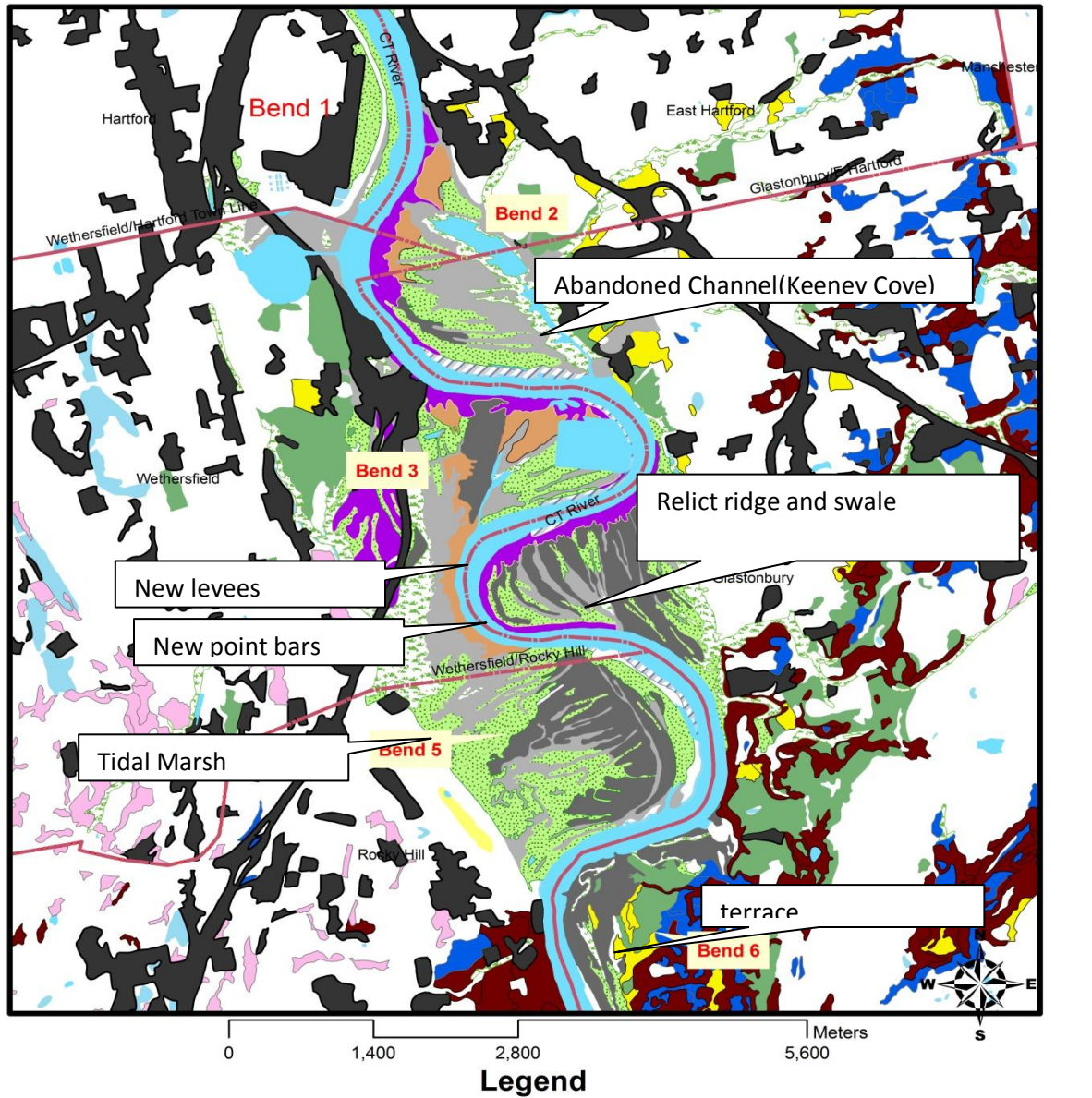


Figure 3.2 Landscape elements present in Glastonbury Meander Reach

Early Geological History

In the last 20,000 years basin geology, changing climate, vegetation, sediments, soils, and sea levels have changed and influenced the Connecticut River (Baker et. al 1988; Patton 1988). The inherited glacial landscape has had the most impact on the hydrology and geomorphology of the Connecticut River (Patton 1988). As the last glaciers melted and retreated northward, the melting ice moved sand and gravel that began to build up in places like Middletown and Rocky Hill, Connecticut. This buildup of sand and gravel led to the formation of dams and large glacial lakes. The dammed bedrock valley that began in Rocky Hill, Connecticut created Glacial Lake Hitchcock a lake that extended 297km north to St Johnsbury, Vermont and 48 km across. Glacial Lake Hitchcock was the largest of 16 sediment dammed lakes that formed in Connecticut. The Lower paleo-Connecticut River flowed into Glacial Lake Connecticut, present day Long Island Sound. The Lower paleo-Connecticut River began to incise due to a change in slope caused by isostatic rebound or a drop in the water levels of Glacial Lake Connecticut (Patton and Horne 1983). This river incision in the lower part of the valley triggered a drop in water levels in nearby Glacial Lake Middletown. Glacial Lake Hitchcock and Glacial Lake Middletown were separated only by a spillway located in New Britain, Connecticut. As Glacial Lake Middletown water levels dropped Glacial Lake Hitchcock began emptying via the New Britain spillway around 15,000 years ago (Patton and Horne 1991; Stone et al. 1998). By 13,500 years ago sea level rose and over flowed into Glacial Lake Connecticut transforming it into a tidal estuary only 40 m below present day levels (Stone et al. 1998). After, or at the same time as the sea overtook Glacial Lake Connecticut, glacio-isostatic tilting raised the lake bed north of Rocky Hill, Connecticut. This isostatic lift resulted in a breach in the Rocky Hill dam

(Stone and Ashley 1995; Stone et al 1998). Since the waters in Glacial Lake Hitchcock had been slowly emptying, through the New Britain spillway, its water depth was only 20-30 m. (Stone and Ashley 1995; Stone et al 1998). Once the Rocky Hill dam was breached it was quickly incised and the portion of Glacial Lake Hitchcock south of the Holyoke Range was entirely drained. Glacial Lake Hitchcock north of the Holyoke Range continued to exist at a depth of 40 m, its drainage controlled by the rate of isostatic rebound (Stone and Ashley 1995; Stone et al. 1998; Ridge and Larsen 1990). The newly formed Connecticut River began to incise the former glacial lake floor around 13,000BP (Stone et al. 1998). Incision was continuous and complete by 12–9.5 ka BP (Stone et al. 1998; Thorson et al. 2014).

The basic morphology of this early Connecticut River is unknown. In theory, there are three types of rivers: straight, meandering and braided⁷. In reality, there are many variations around these broad types, because a river's planform is controlled by local geography. A river's dimensions and patterns will change locally, at the reach scale, as physiography (slope), geology, vegetation, strength water flow and sediment availability changes and either inhibits or facilitates an increase in slope (Knighton 1998; Schumm 2005). Climate change, changes in precipitation rates, and changes to vegetation will trigger a change in sediment load or water discharge. Any significant change in sediment load relative to water discharge will lead to a change in channel adjustment (Knighton 1998). These changes can be achieved by floodplain aggradation or erosion. Floodplain aggradation occurs when slope is decreased. A rise in base level (the lowest point which water can flow), in this case Long Island Sound, is a typical cause of a decreased slope. However, a decrease in sediment supply, or an increase in

⁷ Anastomosing and anabranching are listed as a subcategories of braiding.

the velocity of flow also have the effect of decreasing slope and causing floodplain aggradation. Erosion occurs when channel slope is increased. A decrease in base level could cause an increase in slope, as could an increase in water supply, or an increase in sediment load. Rivers with a gentle slope, such as the present Glastonbury Reach, have low-velocity flow and are less capable of moving sediment coarser than silt. This chapter attempts to ascertain how larger climatic events may have influenced the morphology of the Connecticut River, and in particular the Glastonbury Reach, from the Early Holocene through initial European settlement.

Early Holocene (12,000 - 8000BP)

Paleoecological data and climate modeling indicate that the Early Holocene was a period of extremes, in terms of precipitation and climatic fluctuation (McWeeney and Kellogg 2001). Earth's orbital configuration increased solar insolation and seasonal contrasts. In addition to dramatic seasonal fluctuations in temperature, the Early Holocene is characterized by long periods of drying followed by equally long periods of heavy precipitation. Precipitation was heaviest at the onset of the Holocene, 10,000–9,000 yrs BP. Evidence of extreme drying from 9,270 and 8,830 yrs BP was found in cores taken from wetlands (Pequot Cedar Swamp) (Thorson and Webb 1991; Webb *et al.* 1993; Davis 1983; McWeeney 1999). These cores contained water lily seed, indicative of open water with a low water table, around. After this drying period, precipitation increased in the Northeast (Webb et al 1988). The pollen record indicates that tree species such as spruce, larch, and fir were replaced by white pine, birch, beech, indicating long periods of warmer temperatures (Gaudrau 1988). Plant macrofossils indicate that white pine, yellow and gray birch, oak and a number of other deciduous trees increased dramatically in the Early Holocene and summer temperatures may have

been 8% greater than today, but winters were colder (McWeeney 1999; McWeeney and Kellogg 2001). The increased precipitation levels and warmer temperatures may have led to increased water discharge which may have resulted in flooding and overbank deposition onto floodplains (McWeeney 1999; Forrest et al. 2006; Thorson et al. 2014). Sea level was rising but sediment supply was offsetting it and preventing coastal inundation. Since the river had stopped incising in Connecticut, sediment was either being supplied from upstream or through lateral erosion of the river's floodplain. Sediment supplied from upstream would indicate a straight channel morphology and sediment supplied by lateral erosion would indicate a braided developed in the Connecticut River Alluvial Lowland.

Thorson et al. (2014) contend that during initial incision of the lake bed, the Connecticut River had a braided morphology. Pro-glacial rivers generally have a braided morphology because of the lack of depth, high slopes, and heavy sediment loads provided by the coarse material left by glaciers as they retreat (Knox 1983). However, Knox (1983) contends that in humid eastern Woodland environments, such as Southern New England, straight channel morphologies are more likely to develop in pro-glacial environments. Furthermore, Knox contends that constant and abundant water supply in the humid eastern area is capable of transporting much of the sediment out of the valleys. Regardless, straight river morphologies and braided river morphologies are typically characterized as less than suitable habitats for Hunter-Gatherers. Straight rivers have little or no floodplain and therefore, provide few readily available resources. Braided rivers are highly unpredictable, thereby making potential resources highly unpredictable. The limited Early Archaic archaeological sites located in the river valley

are all classified as temporary camp sites possibly reflecting the low density and unpredictable nature of riverine resources during this period.

Middle Holocene (8000–5000 BP)

The pollen record indicates the fluctuating temperatures of the Early Holocene continued into the Middle Holocene. McWeeney (1999) recovered cores from the Great Cedar Swamp on the Mashantucket Pequot Reservation that contained a charred peat stratum 8 to 15 cm thick, dating to 7440+ 120 yrs BP. This charred peat stratum is indicative of widespread fires due to dry, desiccated vegetation. Nevertheless, sometime in the early quarter of the Middle Holocene, ca. 6500 BP, glaciers re-advanced and temperatures cooled. Evidence of this cooling is also supported by isotope analysis from cores taken from Great Cedar Swamp (McWeeney 1999). In addition, Webb et al. (1993) and Shuman et al. (2005) have examined pollen data acquired from New England wetlands and found that cooler temperatures persisted until 6000 yr BP. The pollen data indicates that Northern pine (*pinus*) was replaced by birch (*betula*) and beech (*fagus*). These tree species are indicative of cooler temperatures and moister climates. This early and relatively short cooling period was immediately followed by a period of warming and drying (McWeeney 1999). By 5400yr B.P. lake levels were low and pollen from moisture dependent vegetation, such as hemlock (*tsuga canadensis*), decreased rapidly (Shuman et al 2005). Warmer than modern temperatures are inferred from the increased levels in hickory (*carya*), pine (*pinus strobus*), oak (*quercus*) and ragweed (*ambrosia*) pollen (Shuman et al. 2005; McWeeney 1999). This warming and drying evidence coincided with the Altithermal of the Great Plains and the Hypsithermal of the Midwest. However, the lack of evidence for widespread and intense dry climatic conditions in New England indicates that the cause for dry conditions may be more

directly related to local geomorphological conditions rather than regional climatic changes (Simon 1991). In southern New England climatic fluctuations, alternating between wet and dry conditions may have been the extent of the Hypsithermal. In Connecticut, the most widespread drying likely occurred between 4300 BP and 3200 BP and the overall trend was for a 3-7 C increase in temperature (Shuman et al. 2005). Despite the lack of intensity, these fluctuations could have been severe enough to impact water and sediment supply, as well as taxa depending upon the local geomorphic such as distance to coast, small-scale gradients in climate, soil conditions, and elevation (Simon 1991; Meltzer 1999; Shuman et al. 2005).

The increase in temperature likely resulted in continued sea level rise in Long Island Sound. The rate of sea level rise was so rapid that coastal submergence began, despite the increase in sediment supply from 52 cm/10³ yr to 81cm/10³ yr in the Mid Holocene. (Gaudreau 1988;Patton and Horne 1991; Stone and Ashley 1992). The coastal inundation resulted in the submergence of the Lower paleo-Connecticut River around 4200B.P. (Patton and Horne 1991). This submergence would have resulted in a reduction in stream power and massive floodplain aggradation in the upper parts of the valley (Webb and Webb 1988, Knighton 1998). Thorson et al. (2014) has documented sedimentary evidence for this transition floodplain (6.4–2.7ka). This massive floodplain aggradation resulted in deep and rapid burial of any archaeological deposits made prior to this time frame (Thorson et al. 2014).

When the Lower Connecticut River became a mixture of back water coves and tidal marshes this may have caused a reduction in the sediment transport rate from the alluvial lowland and resulted in a more stable floodplain. Flood events were the result of hydraulic ponding (Thorson et al. 2014). The hydraulic ponding mechanism results

in slow floods with waters hold at flood stage maximum for days and weeks essentially creating transient lakes that draped the CRAL floodplain with a layer of silt and clay every few years (Thorson et al. 2014). This transition to floodplain aggradation and stability coincides with a shift in the archaeological site distribution (Jones 1999; Dewar and McBride 1992; Thorson et. al 2014). Chapter 2 demonstrates that there is a tendency for sites to move towards perennial stream with time and that by the Late Archaic sites are strongly correlated with large river valleys. Therefore, it is possible that the meandering regime with backwater flooding and transient lake-like floods may have created a unique environment that was, in part, responsible for the remnant settlement patterns (Nicholas 1998; Jones 1999; Thorson et al. 2014).

Late Holocene 5000–400 B.P.

Temperature and moisture fluctuations continued into the Late Holocene accompanied by flooding events which altered the local environment and landscape (McWeeney 1999; Brackenridge 1988). “Little Ice Ages” occurred at 4,330 yrs BP: 3920, 2550, 1550, and 650 yrs BP (uncalibrated) and pollen records show an increase in spruce, chestnut, and hickory during this time period. (Deevey and Flint 1957; Webb et al. 1983; Shuman et al 2005). Further evidence for these cooler and moister conditions comes from lacustrine clay deposits in Massachusetts and Connecticut. These deposits contain preserved leaves, fruits, and twigs from hickory, butternut, white pine, hemlock, and fir needles dating to 2680 ± 30 yrs BP. The fir needles are a strong indicator of cool moist conditions in Connecticut at this time (McWeeney 1999). However, there is also evidence for periods of warming represented by the presence of certain vegetation. Sourwood (*Oxydendrum arboreum*) was located at a coastal archaeological site in Greenwich, Connecticut and black walnut (*Juglans nigra*), another indicator of warmer

temperatures, was found at the Connecticut River's Morgan site in Rocky Hill, Connecticut. Temperature and moisture fluctuations were accompanied by a continued rise in sea level.

Patton and Horne's (1991) submergence curve provides a starting point for considering the effects of sea level rise on the Connecticut River and its estuary. In Patton and Horne's (1991) study, vibracores taken from the lower Connecticut River, from Old Lyme up to Cromwell Connecticut showed buried geomorphic surfaces. Calculating the long-term sedimentation rates allowed Patton and Horne to establish a rate of coast and river submergence from the Late Holocene to present day. From 4000 to 1700 yr BP sea level rose at a rate of 1.7mm/year at the same time sediment deposition rates fell. This combination allowed for continued coastal submergence and conversion of the Lower Connecticut River valley's floodplains into open backwater coves (Patton and Horne 1991). In the Lower Connecticut River Valley floodplains and terraces became dominated by saltwater and the upper portions of the Lower Connecticut River valley became a less efficient conduit for medium to fine grained sandy sediment. The floodplain surface rose at a rate of 0.9 mm/yr (Thorson et al. 2014). At 1700 yr BP the rate of submergence slowed to only 1mm/yr. This slower rate may have persisted for 1000 years (Patton and Horne 1991). The decrease in submergence caused freshwater marshes to form and prograde over the backwater coves and the remaining floodplain of the Lower Connecticut River valley. As sea level rates stabilized by 2300–1700B.P. this likely resulted in reduced flooding and floodplain stability (Thorson et al. 2014). However, the overall stability may have been partially achieved through slow and steady meander formation, migration, and avulsions. Meander formation, migration and possibly avulsions would have been a regular

occurrence. Despite flooding the floodplain remained vegetated (Thorson et. al 2014). Unidentified wood charcoal in the Cromwell Meadows is evidence that the floodplain in the region just south of the study area was vegetated at 2360BP (Patton and Horne 1992). In addition, black gum and hickory wood charcoal recovered from archaeological sites in the Glastonbury, Hartford, and Windsor Reaches indicating the existence of vegetated floodplain in these reaches 3700-800 B.P. (McWeeney 1999).

The Late and Late Woodland Period site distributions indicate that during this stage the large river valley was the focus of the settlement and resource exploitation (Thorson et al. 2014). Early Woodland and Middle Woodland sites are fewer in number. Thorson et al. (2014) contend that this decrease in site numbers is due to an increase in the river's volatility but, this decrease in site numbers for these periods occurs statewide. More detailed georchaological research needs to be conducted to determine if this slight decrease in site numbers is due to the changes in the river's volatility which impacted settlement or merely eroded evidence of settlement in the study area.

3.4 Meander Migration and Alluvial Landscape Changes

The rate of coastal submergence has doubled to 2.2mm/yr over the last 350 years but the sediment accumulation rate over the last 330 years has, on average been four to five times faster than any time previously (Horne and Patton 1992; Lewis and Stone 1991; Webb and Webb 1988). Since 1915 there has been little net change in bathymetry suggesting that the bed of the estuary may be in equilibrium with its bedload sediment supply (Horne and Patton 1989). Thus, despite the increase in stream power and base level the short term view of the Connecticut River is one of a stable geomorphic system capable of efficiently transporting medium-to fine-grained sand into its estuary and

remaining in balance with the rate of coastal submergence (Horne and Patton 1989; Patton and Horne 1992). Nevertheless, the river's morphological changes in early history and those depicted in historical maps spanning 350 years clearly show the study area to have undergone significant changes in meander morphology. Over the past 350 years the Glastonbury meanders have avulsed, rotated and enlarged and shifted south and east taking approximately.

Meandering occurs when base level or sediment load relative to water flow changes. Lengthening or shortening the channel through meander formation, meander migration, or meander cutoff are the most frequent ways of changing the local water surface slope. Meander migration can occur in several different forms: extension, translation, rotation, enlargement and combinations of these forms (Figure 3.3).

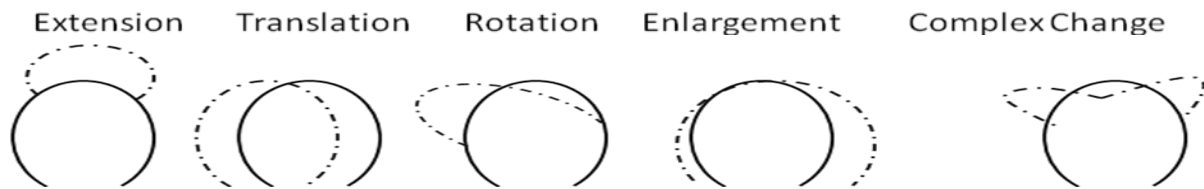


Figure 3.3 Planform changes: typical meander migrations. Adapted from Brown (1997)

Differences in the rate of meander migration can produce cutoffs; a chute cutoff is produced when a flood cuts through any part of a meander loop, a neck cutoff is when the entire loop is cut off from the main channel resulting in an oxbow lake. Some rivers change their location by adopting a completely new course after a flood, this is called avulsion. The new location will generally be the lowest unobstructed path on the floodplain (Brown 1997). Neither avulsion nor meander migration occur freely over the entire floodplain because within a floodplain there are much smaller meander belts. A meander belt is defined as an area of the floodplain that is affected by the meander migrations occurring over a specific period of time. Meander migrations and cutoffs

that occur during the same period of time appear to be confined to a single belt thereby leaving large portions of the floodplain untouched for hundreds to thousands of years (Brown 1997:26). Lowland rivers in the eastern United States have a remarkable lack of mobility caused by generally resistant banks formed by cohesive silty clays, and peats and rather low stream power, non-flashy regimes, and low regional slopes (Brown 1997:27). Over the past 350 years the Glastonbury Reach despite, the increase in sediment load, and base level, the channel has actually been stable and only meandering within a small portion or belt of the floodplain. This relatively limited meander migration space at specific periods in time may, in part, be responsible for the fragmentation of the archaeological record.

Therefore, determining the rate of stable of meander migration is relevant for understanding the current archaeological settlement pattern. To determine rates of equilibrium and stability, the reach's documented history needs to be examined (maps and gauge data). This historical data can reveal the time periods required for a reach to develop characteristic forms and the time period over which such forms are likely to persist (Knighton 1998: 162). Furthermore, it can define floodplain areas that have been too eroded by documented historical meander migrations to engage in archaeological survey. A detailed examination and analysis of the Glastonbury Reach's historical data, from 1600AD to present, follows in Chapter 4.

3.5 Summary and Conclusion

Understanding when, why and how streams transport, erode, and deposit sediment is necessary to understand archaeological settlement patterns (Goldberg and Macphail 2006). However, there is no single variable that dominates river morphology. While independent controls (climate, hydrology, geology), in large part, constrain channel

morphology, it is the local alluvial controls gradient, sediment load, and water discharge that determine reach processes and dictate channel morphology.

A variety of morphological or pattern changes can occur as a result of channel slope, water flow and sediment load response to geologic, geomorphic, climatic/hydrologic or land use changes. Therefore, morphologies can be associated with certain parameters. For example steep slopes and high sediment loads will produce braided streams; while gradual slopes with heavy sediment loads may produce a meandering stream (Brice 1983). The CRAL had a developing floodplain meandering regime about 6.4 – 4.2ka (Thorson et al. 2014; Patton and Horne 1992). This transition to a meandering stream coincided with a settlement shift. However, sedimentary evidence from Hartford indicates that a period of increased volatility occurred around 2700ka. More detailed geoarchaeological research needs to be done to determine how this stability and volatility manifested itself in the Glastonbury Reach and how it impacted the remnant settlement pattern.

The alluvial forms and processes of alluvial environments must be delineated and understood because they affect the archaeological site formation, survival and settlement pattern bias (Brown 1997; Rossingnol and Wandsnider 1992). A more detailed study of the Glastonbury Reach, beginning with the historic period (Chapter 4) is required to provide a diachronic context for archaeological settlement patterns.

Chapter Four

Geological Constraints and Historic Planform Analysis

4.1 Introduction

This chapter examines the known geologic constraints of the reach and the historical planform dynamics to identify rates and patterns of meander migration. This chapter

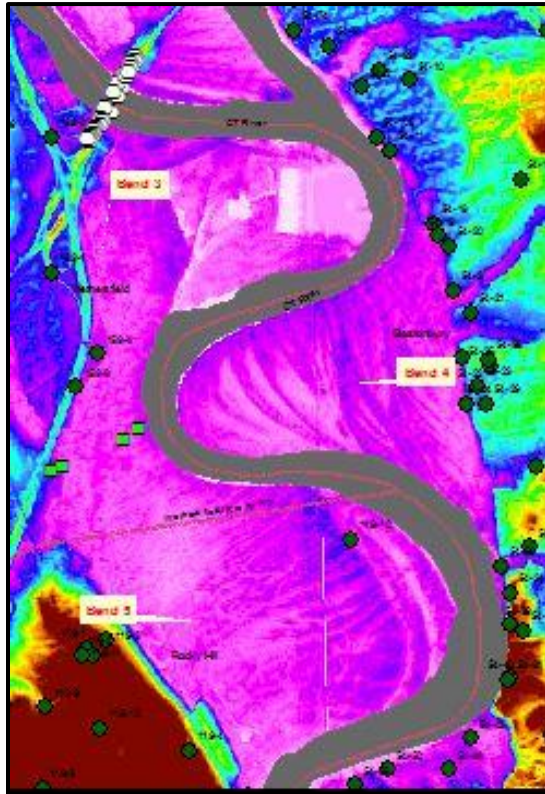
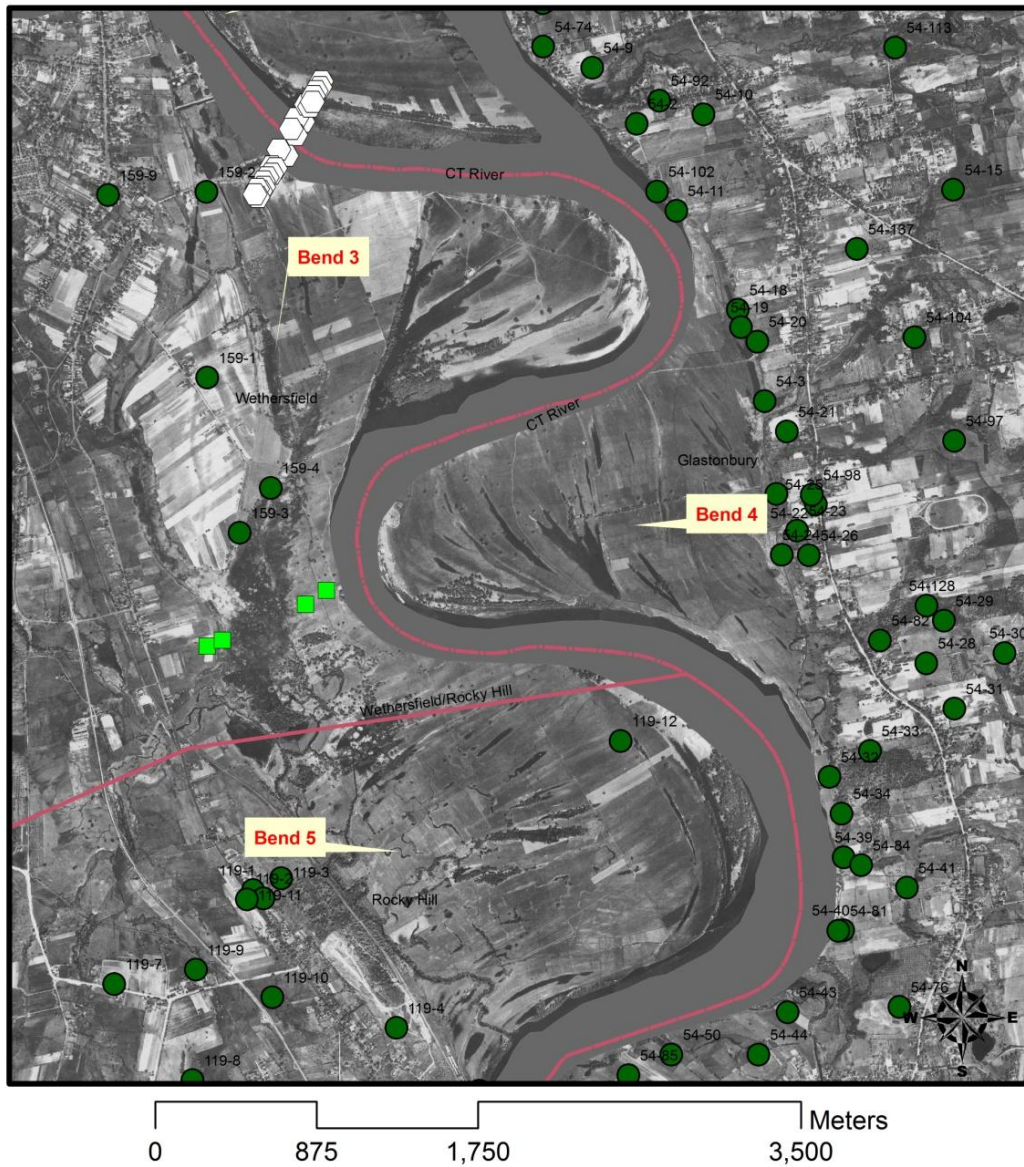


Figure 4.1 Digital elevation model (10ft) showing floodplain landforms .

begins with a description of the geological factors that may have influenced reach migration. Given these geological constraints, a historical planform analysis (1640–1938) of the Glastonbury Reach that focuses on the shape and position of the reach over time is presented. This historical planform analysis focuses on meander geometry, in the form of channel length, width and radius of curvature as well as their roles in sediment transport (slope and water flow) and channel stability.

When viewed at this scale over such a short time frame, rates and patterns are revealed.

Most significantly, the historical planform analysis reveals that the historic meander migrations alone did not create all of floodplain landforms visible in the digital elevation models and aerial photography (Figures 4.1 and 4.2).



Legend

Connecticut River 1934
 StudyArea_AllSites
 Coring Locations
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Figure 4.2 Archaeological site distribution laid over 1934 aerial photography.

4.2 Reach Geometry and Geological Constraints

The reconstruction of past fluvial morphology requires some imagination constrained by observation of contemporary channel behavior (Bristow 1996). Although links between stratigraphic section and channel pattern have been made, they are by no means unambiguously predictive indicators of channel morphology or processes but, with assumptions laid out some planform reconstructions can be done (Allen 1964; Miall 1977; Bridge 1995; Bristow 1996). Actively meandering reaches adjust their shape and location (planform) according to spatial and temporal variations in water discharge, sediment load, bank material properties, and adjacent reach morphology. Therefore, the following can constrain meander evolution: existing geology, topography, and existing bend morphology. Reconstruction of ancient fluvial morphology is especially difficult because it requires an assemblage of the same planform data (channel width, depth, slope, channel morphology) through time. The existing parameters for discharge, sediment, channel bed slope and landforms, are used to guide and constrain any interpretation of past planform dynamics.

The gages at Hartford (north of Hockanum River) show maximum discharge during the 1936 flood (36'-highest flood on record) at Hartford (USGS gages: 01190070, 01193000) was 313,000 ft³/s and at Middletown 267,000 ft³/s. This decrease in maximum discharge downstream is in part due to the bedrock geology downstream which forms a hydraulic dam (Thorson et al. 2014). The stable meanders of the Glastonbury Reach were created once the floodplain developed and local slope was reduced (rise in sea level). The floodplain of the Connecticut River was fully formed around 6.4 ka –4.5 ka. (Thorson et al. 2014; Patton and Horne 1992). The combination of more cohesive banks a reduction in slope, which created a hydraulic dam, and

possible reduction in stream power contributed to the development of a stable meandering regime.

Regular sinuous meanders serve to slow water velocity and reduce the sediment load downstream. Due to the geological constraints, downstream as well as upstream, the Glastonbury Reach is consistently and constantly adjusting its planform to balance the constant fluctuations in water discharge or sediment load. If there is significant fluctuation in variables the planform adjustments will also be more significant. Planform adjustments occur through channel widening, narrowing, meander migration, cutoffs, and/or avulsions. At times these adjustments occur slowly, imperceptibly over hundreds of years but at other times river adjustments are rapid and result in a dramatic change to the planform and landscape. Over the past 350 years the Glastonbury Reach appears to have changed from a meandering channel morphology (almost anabranching) to a straight channel morphology and back to meandering channel. The geological factors within the reach that have directed meander migrations are: bedrock, slope, and the postglacial deposits (MIS2 –MIS1) that shaped the valley. The basalt ridge, extending in a northwest direction from the southern end of the Glastonbury Meanders, as well as glacial lacustrine terraces in Glastonbury and Hartford, Connecticut as well as the activity of the Hockanum and Park Rivers and other tributaries constrain the meander evolution to 30sq km. Within this area, the layout of the floodplain landforms, as well as degree and direction of slope further constrain channel course and bend migration.

For example, according to the digital elevation model, at the outset of the reach the valley slopes gently to south and west (Figure 4.3) which may contribute to the first

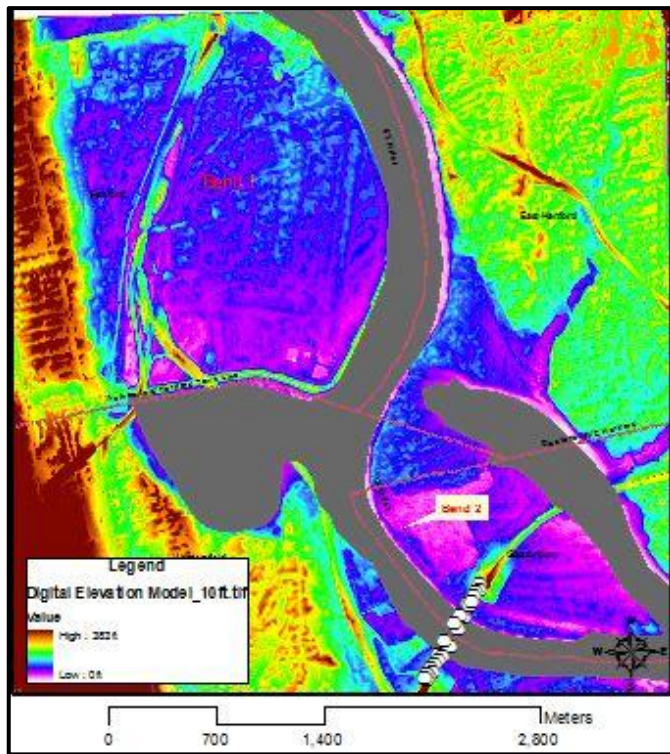


Figure 4.3 Digital elevation model showing the slope at the south west portion of bend 1.

meander bend's proclivity to migrate west and south (prior to modern intervention). Furthermore, at the second meander bend difficult to erode postglacial deposits (Putnam Bridge locale) may force this bend to migrate east (Figure 4.4). However, on the east bank these difficult to erode postglacial deposits are located over 1 km away from the present day stream.

After this meander bend the postglacial deposits are equidistant

from the center of the valley down to the basalt ridge in Rocky Hill, Connecticut (Figure 4.4). Therefore meander bends 3, 4, and most of 5 are free to migrate across the entire floodplain. Meander bend 6 is constrained by the basalt ridge and by difficult to erode terrace deposits (Figure 4.4). These outlined geological constraints are likely to have existed in the past and will be used to guide the historic planform analysis as well as Pre-contact reconstructions.

4.3 Historic Planform Analysis

The historic planform analysis is used to identify patterns in planform adjustments as well as rates of migration. The historic planform analysis focuses on meander geometry in the form of channel length, width, radius of curvature, and rates of channel stability and change.

Estimation errors are expected to come from georeferencing or digitizing errors.

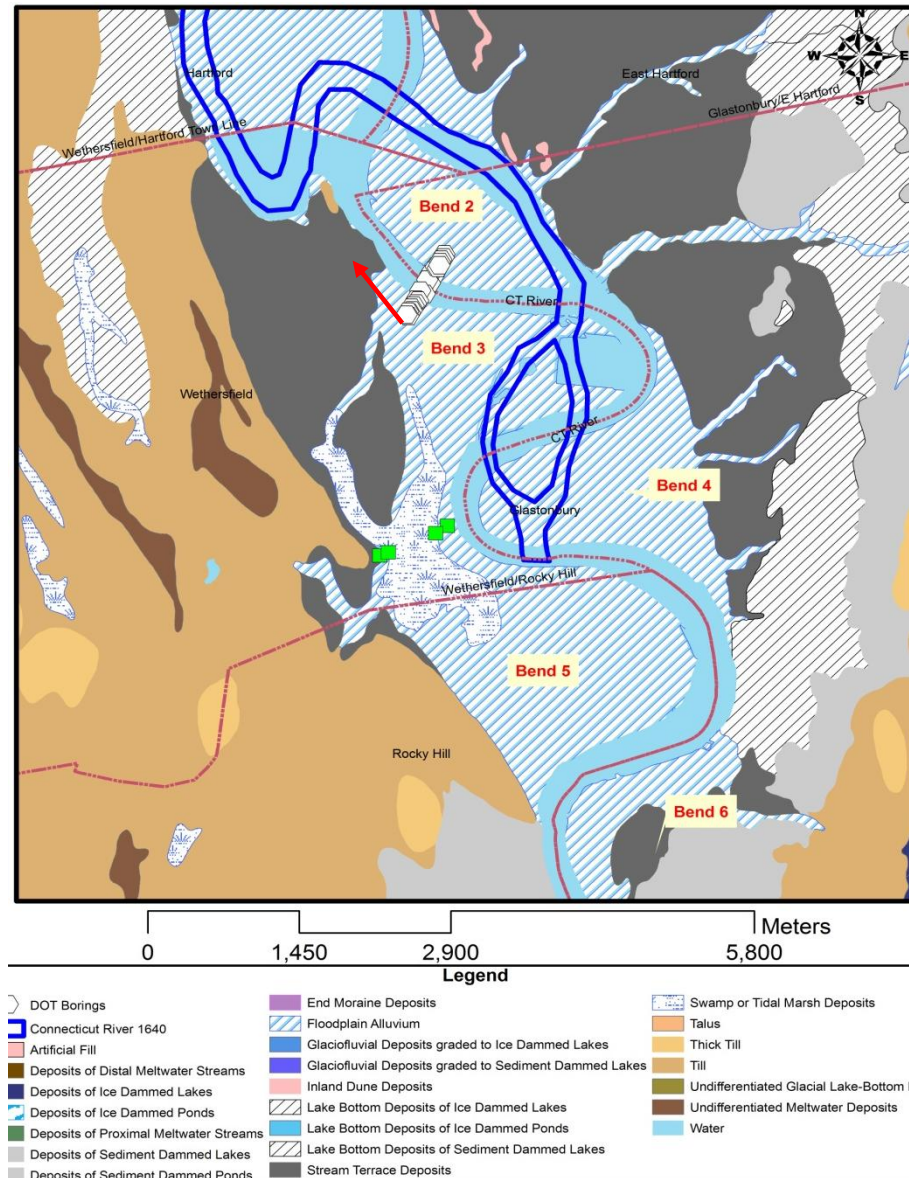


Figure 4.4 Present Connecticut River course and the 1640 river course with the geological constraints (bedrock, slope, and landforms). Red arrow points to post glacial deposits constraining migration of meander bend 2.

In an effort to discern phases and patterns to predict likely areas of preservation over time the reach will be analyzed working backwards from present (1938–1640).

Analyzing the planforms in this manner revealed three distinct phases of planform adjustment and stability during this 350 year period. The current planform of the Glastonbury Reach is part of the meander formation and migration phase (1938–1800);

which is composed of three distinct periods; in phase 2 the Glastonbury Reach had a straight channel morphology (1800–1700); in phase 3 the Glastonbury Reach consisted of meanders and islands, an anabranching planform(1683–1640) (Figure 4.5) The identified constraints, patterns, and rates of migration in the historical planform analysis are assumed to be normal adjustments and average rates of migration. Phase I (1800 to present), the meander formation and migration phase, is comprised of three periods of increasing sinuosity.

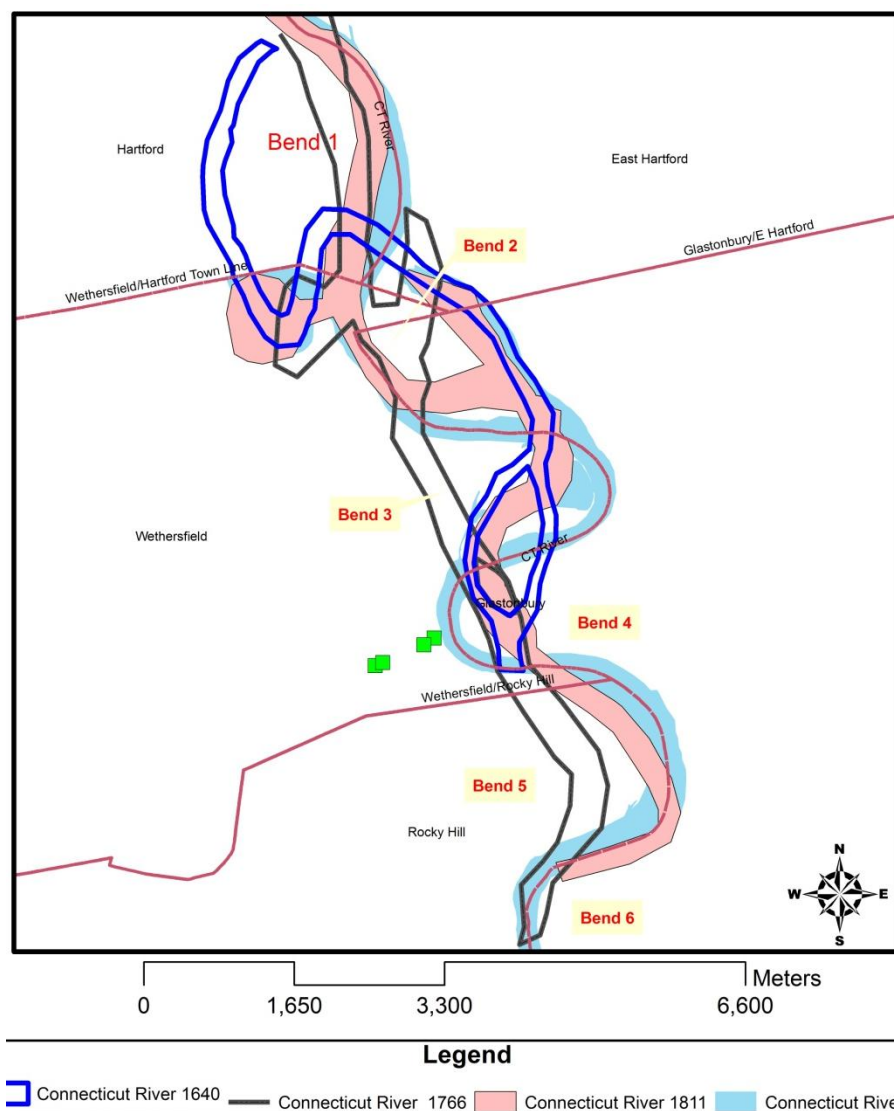


Figure 4.5 The historic planforms overlaid with each other. The 1640 (blue outline) channel has an anabranching morphology; the 1766 (black outline) channel has a straight morphology; the 1811 (pink) channel is beginning to meander; and the present channel (light blue) is meandering with moderate sinuosity.

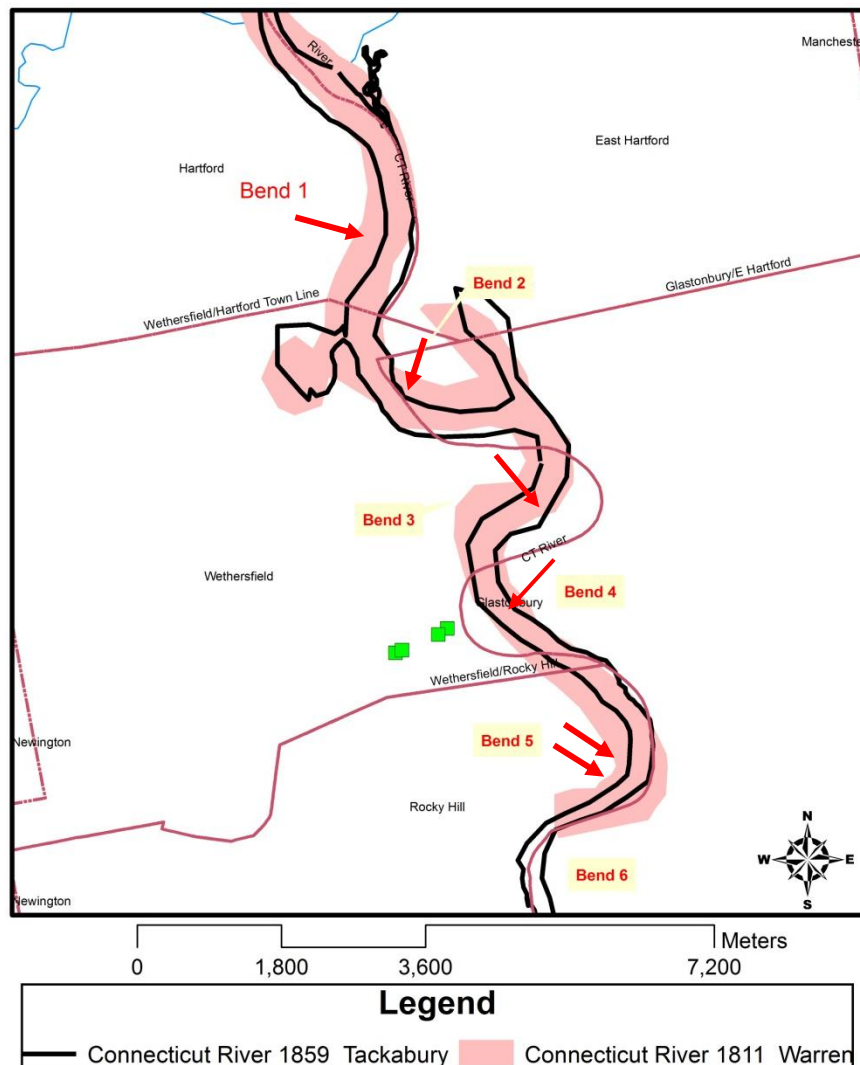


Figure 4.6 The 1811 channel (Warren Map) and the 1859 channel (Tackabury map). Arrows indicate the direction of meander migration.

In the first period, 1800–1859, of Phase 1 (Figure 4.6) the planform was just beginning to meander. The sinuosity increased over time with the channel first migrating south and then west. This straight to meandering channel transformation is typically associated with increases in bed load and stream power (Knighton 1998). The 1811 channel depicted, in

figure 4.6, is based on the 1811 Warren map. The Warren map depicts the channel as twice the width of the present day channel so channel narrowing due to increased runoff in the 19th century is a real possibility. When comparing the 1811 channel to the channel in later maps it is apparent that downstream meander change was initiated as meander bend 2 extended.

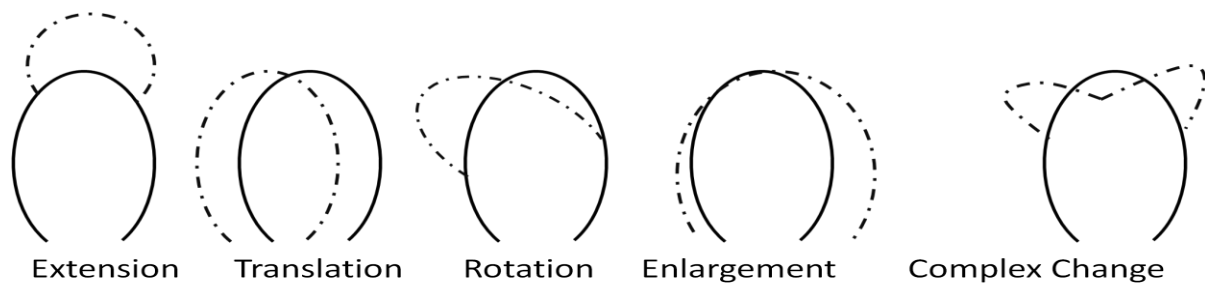


Figure 4.7 Planform changes and geometry: Typical meander changes. Adapted from Brown (1997).

This meander extension then initiated the rotations of meander bends 3 and 4 (Figure 4.7). The meander migration pattern resulted in erosion on the outer portion of the bend and upper portion of the floodplain as well as floodplain aggradation on the opposing inner bends and lower portion of the floodplain. The southerly migration may indicate that meander bend 2 was affected by increased discharge from tributaries as well as the effects of the hydraulic dam further downstream. Increased discharge from tributaries may have increased stream power in this portion of the meander. If the 1811 rendering is accurate, there is a possibility that channel infilling and channel bar accretion was the predominant fluvial process in the early 19th century. It is possible that this high discharge as well as increased sediment load initiated the riffle-pool sequence necessary for meander formation (Knighton 1998 pp. 193-201).

From 1859 to 1895 meanders continued to rotate in a southerly direction (Figure 4.8). Keeney Cove appears more truncated during this period but, cartographic error cannot be completely ruled out. Meander bends 1 and 2 migrate south at an estimated rate of 2.6m/year. Meander bend 3 also rotated south, at an estimated rate of 5m/year. Meander bend 4 migrated south and west.

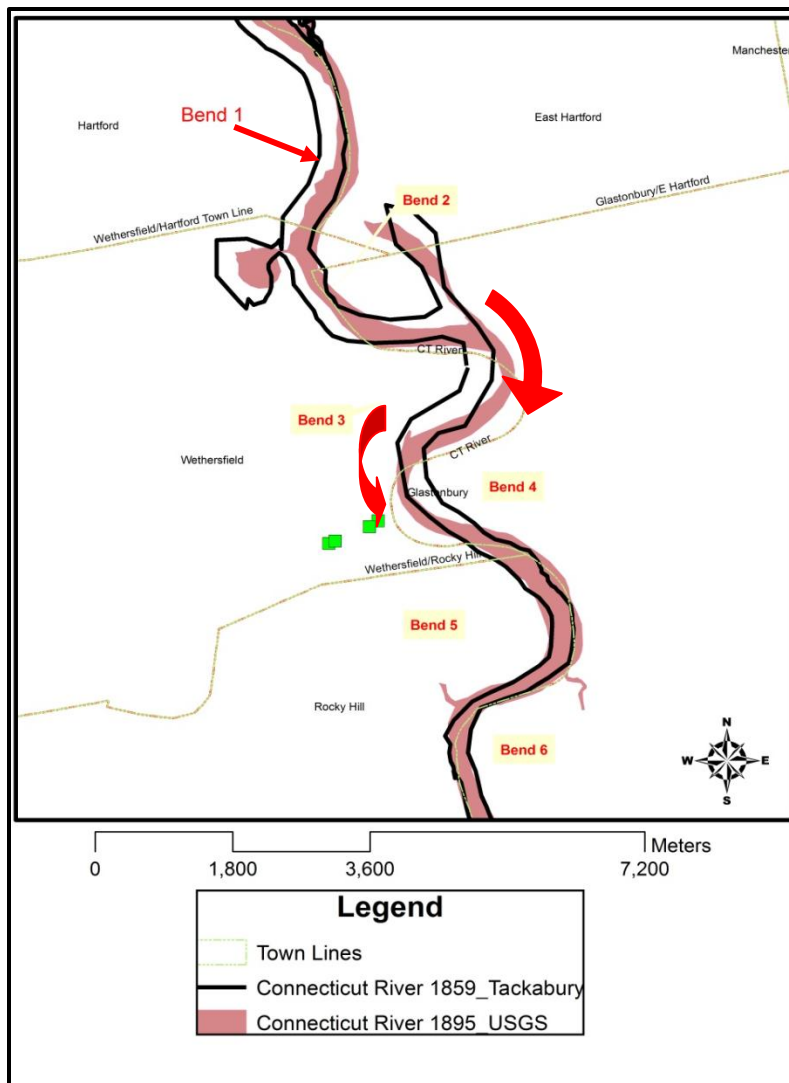


Figure 4.8 The 1859 channel (Tackabury) outlined in black over the 1895 channel (USGS). Green town lines show the current channel.

The 1859 channel, as depicted in the Tackabury map, depicts a much wider meander. This could be a cartographic error since the channel in the 1859 Tackabury map is consistently wider than the USGS map but, a wider channel cannot be completely ruled out.

Moreover, meander bend 5 is depicted as more narrow in the 1859 Tackabury map than the 1895 USGS topographic map. Thereby, indicated that meander bend 5 actually widened and eroded both sides of the bank.

From 1895 to 1934, meander bend 2 migrated approximately 100 meters south (Figure 4.9). Water flow eroded the outer banks of the meanders which resulted in erosion of the upper portion of the floodplains. Meander bends 3 and 4 also migrated south through rotation, which resulted in floodplain aggradation in the lower portion of the floodplain bends. Meander bend 3 migrated at a faster rate than meander bend 2, approximately 300 meters during the same 43 year period. Meander bend 4 rotated south at a rate of 250 m/43 years. Meander bend 5 migrated in the form of extension.

The extension occurred in a northeasterly direction into Glastonbury, Connecticut. It appears that the lower portion of meander bend 5 was constrained from migrating south by either bedrock or difficult to erode terrace. Meander 5 migrated at approximately the same pace as meander bend 2. On average, the rate of meander migration for this period ranges, from 2.3-6.3 meters/year; with meander bends 3 and 4 migrated at over

twice the rate of meander bends 2 and 5.

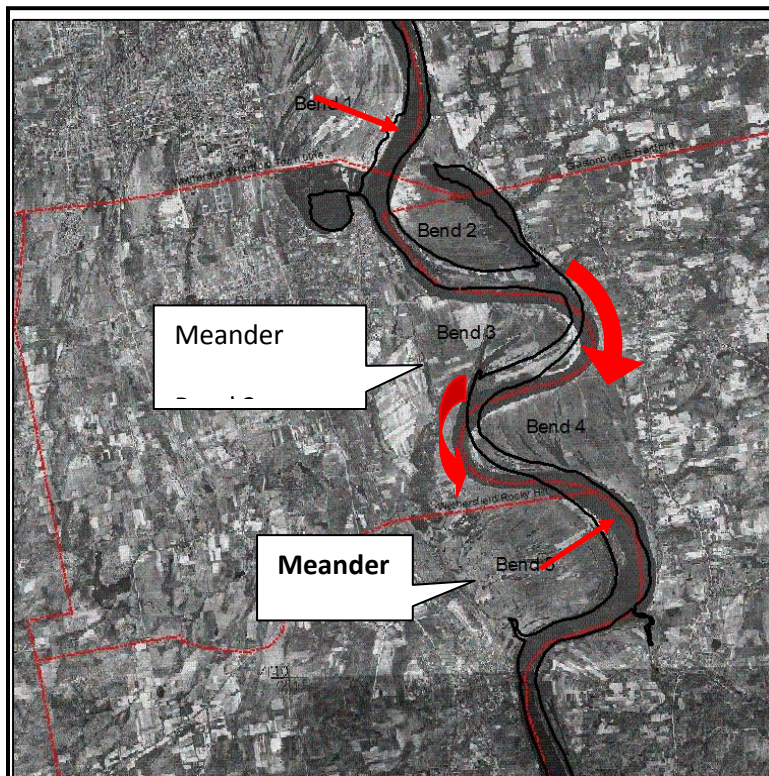


Figure 4.9 The 1895 channel outlined in black over the 1934 aerial photograph (red town lines show the current channel).

During the 18th century (Phase II) the Glastonbury Reach had a straight morphology. During this century, deforestation, and Colonial agri-pastoral practices had the effect of warming and drying the soil (Cronon 1983; 122). Initially the land clearing would have resulted in an increased water supply.

Straight channels increase the efficiency of moving flood waters through the area, but can cause downstream scour due to excessive energy (Knighton 1998). The straight channel may have developed as a result of increased runoff and/or higher than average flood waters that caused meander cutoff. However, eventually this increased runoff results in increased soil erosion. Continued soil erosion may result in an increase in bed load which in turn initiates the

pool riffle sequence and meander formation (Knighton 1998). Nevertheless, the 1766 Park map and 1792 Blodget map indicates the reach maintained a straight morphology for the entire century. Meandering is depicted as just beginning in the 1811 Warren map (Figure 4.10). Prior to the straight channel morphology the Glastonbury Reach

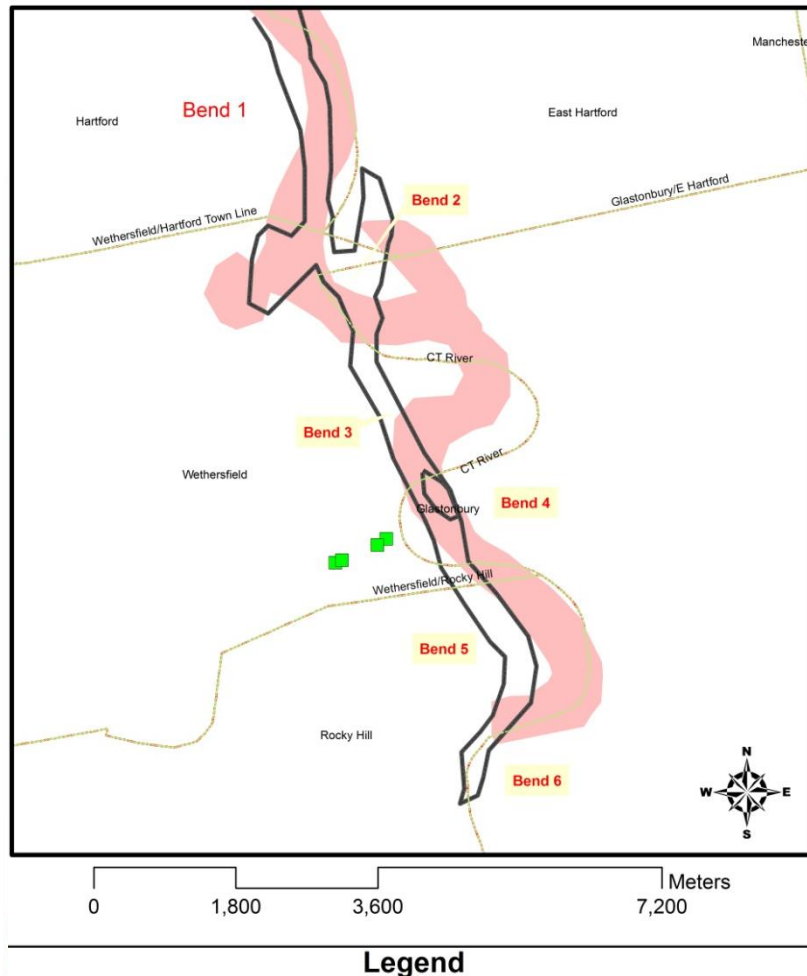


Figure 4.10 18th century straight channel morphology (Park) with early meandering as depicted in 1811 channel (Warren).

consisted of a large oxbow (meander bend 1) and mid-channel islands (Pennywise and Wright's). The 1640 reach was described and depicted as "S" shaped channel with vegetated islands (Figure 4.11). This morphology could be classified as anabranching, the stage between meandering and braided morphologies. Mid-channel islands develop in reaches with heavy bed load and/or local incompetence. The

islands develop from large, low angle point bars which are prone to chute dissection. Islands caused by channel dissection can cause bank scour or channel widening but, these mid-channel bars are considered temporary phenomena (Brown 1997; Knighton 1998). Island formation indicates that that the slope and sediment load threshold for a

meandering stream to morph into a braided stream was about to be surpassed in the Glastonbury Reach. The meandering-anabranching phase may have existed for some time prior to English settlement. It was reported that The Native Americans used the

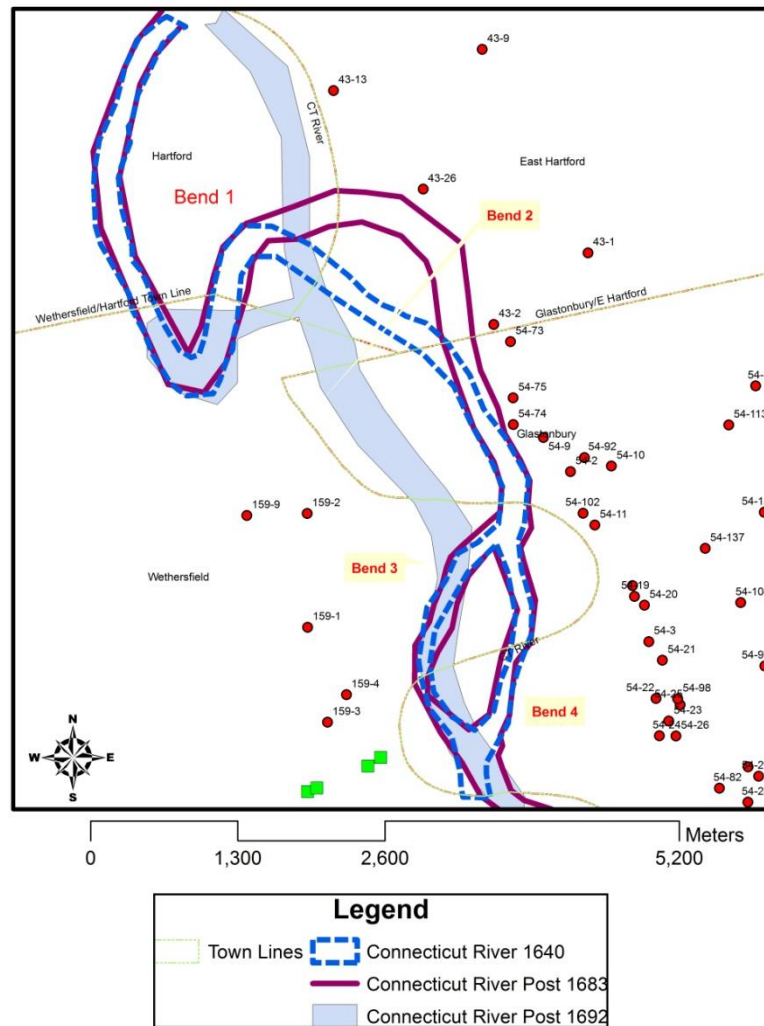


Figure 4.11 The 1640 Glastonbury Reach outlined in blue and shown with present day channel

island to meet and play games.

They called the larger mid-channel island in the Glastonbury Reach *Mannahannock* (Great Laughing Place) (Stiles 1904; Cutter 1912).

Since the island was used only as a “meeting place” it is possible that the Native American inhabitants had environmental concerns or socio-cultural restrictions with respect to the islands. With the arrival of the English settlers

the island became a permanent place of settlement for many

colonists. The island was later renamed Wright’s Island, after its largest landholder. The Wright’s owned the land from the 17th until the island was completely moved (swept into the Wethersfield bank and/or merged with the Glastonbury bank) when the east

bank channel disappeared at the end of the 18th century.⁸ It is impossible to know how long the “S” shape and mid-channel islands existed prior to 1640. However, given the reported vegetation, and estimated size of the island, the 1640 planform may have existed for at least 150 years prior to English settlement. A hurricane and flood in 1693 resulted in the creation of a hook in the first meander. Another 17th century flood resulted in the cutoff of meander bend 1 and meander bend 2 and formed the straight channel that existed throughout the 18th century (Figure 4.10).

The fact that the planform changed from a meandering morphology, to straight channel morphology, back to meander morphology may indicate that the temperate climate and geological conditions favor a meandering planform. The straight channel morphology may have been a temporary response to the disturbance caused by the 1693 hurricane. Once the disturbance had been mitigated by alluvial adjustments its tendency was to return to its previous state. The meander morphology appears to be the reaches most stable morphology and meander adjustments are the reaches way of mitigating disturbances to discharge or bed load. This disequilibrium and adjustment towards equilibrium sequence took approximately 250 years. The Glastonbury Reach takes approximately 125-300 year cycle to reach a state of equilibrium. The reach took approximately 125 years (1683-1811) to return to its meander morphology, and then took another approximately 125 years (1811-1936) for the meanders to adjust to the present stable meander morphology. Meander bends have migrated an average of 3.5 m a year. Therefore, it would take the first meander (bends 1 and 2) approximately 375 years to migrate across the 1.3km section of the valley. The second meander (meander

⁸ The Wright’s dock, which occupied the north side of the island reportedly “landed” on the west bank of the Connecticut River, Wethersfield, Connecticut, which allowed the Wright’s to lay claim to this land in Wethersfield in 1790 (Stiles and Adams 1904).

bends 3 and 4) would take twice as long to migrate across the 3 kilometer wide valley. However, the first meander has migrated at approximately half the speed of the second meander. Furthermore, the second meander appears to only begin migrating after migration is initiated in the first meander. Therefore, the second meander's shape and position is directed by the shape, position, or movement of the first or second meander bends. Meanders bends 5 and 6 are also constrained in their migrations. The geology surrounding these lower meanders essentially prohibit the meanders from moving farther south than Rocky Hill. Given these identified patterns and rates of migration of meander morphology the impacts of these historically documented meander migrations on the archaeological site distribution are examined.

4.4 Historic Planform Dynamics and the Archaeological Site Distribution

Historic planform analysis (1638-present) revealed that the current stable meander morphology is a direct product of only 150 years of downward and westward meander migration. These planform changes took place in a singular meander belt due to the geological constraints, basin geomorphology, as well as previous channel morphology. The constraints and elements directing the reaches evolution are a basalt ridge line at the southern tip of the reach post glacial deposits that inhibit meander development, as well as local slope and changes to the discharge and sediment loads. These factors have created a scenario where the middle of the reach, meander bends 3, and 4, are relatively unconstrained but the top and bottom of the reach, meander bends 1, 2, 5 and 6, are constrained. The movements and constraints of the past 350 years, natural as well as man-made, are examined to delineate and separate out their impacts to the archaeological site distribution.

The 1934 aerial photography (prior to construction of Brainard Airport, Hartford, Connecticut-Bend 1) serves as the baseline for analyzing planform changes and examining the archaeological site distribution. The archaeological sites in the Glastonbury Reach are distributed over the floodplain and terraces near coves, marshes, tidal flats, on meadows, ridges, in addition to stream tributaries and surrounding quarries (Figure 4.12). There are approximately 60 precontact archaeological sites on floodplain and terraces that overlook the Glastonbury Meadows floodplain. A synchronic count reveals the Late Archaic period site landscape distribution consists of 12 floodplain sites, 19 terrace sites, and 11 tributary sites. The Terminal Archaic record consists of 3 floodplains sites, 5 terrace sites and 7 tributary sites. The Early Woodland record consists of 4 floodplain sites, 6 terrace sites, and 4 tributary sites. The Middle Woodland record for the study area consists of 6 floodplain sites, no sites on the terraces, and 4 sites on the tributaries. Finally, the Late Woodland record consists of 6 floodplain sites, only 1 terrace site, and 6 sites on the tributaries. The site distribution within each meander bend will be examined individually, in order to gain an understanding of how the planform dynamics may have affected these remnant settlement patterns.

Historic Planform Dynamics and Archaeological Site Distribution: Meander Bends (1–2)

No archaeological sites have been located on the floodplains of the first two meander bends. However, this locale has been completely reworked with the construction of an airport and runways in the 1940's as well as flood pump controls, stations and levee construction. Historic maps reveal that at about 1640 A.D., meandering in this section of the reach was restricted to the southernmost part of the bend where it formed a large meander at the intersection of Hartford, East Hartford, Wethersfield, and Glastonbury.

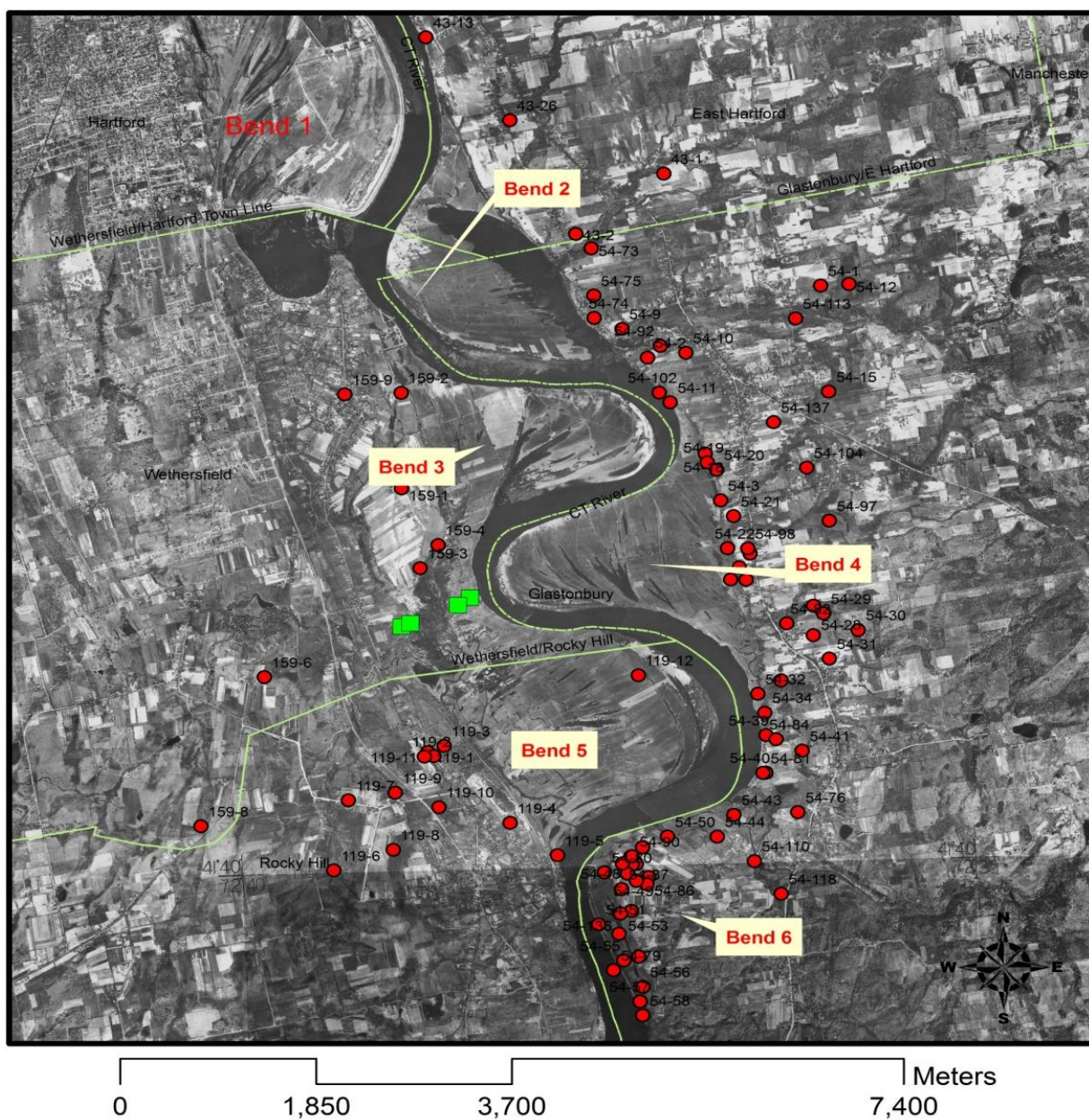


Figure 4.12 Glastonbury Reach in 1934 with Pre-contact archaeological site distribution.

There were six documented storms in the 17th century that caused widespread flooding along the Connecticut River. The first recorded flood for Wethersfield occurred in July or August 1683 and resulted in the rotation of meander 1 into East Hartford (Thomson et al. 1964; Kinnison et al. 1938) (Figure 4.13). This resulted in a meander that was pushed up against the low terrace in East Hartford which resulted in its constraint and awkward hook shape. The next major flood to impact Wethersfield, Connecticut was in February 1692. According to records, this flood resulted in the straightening of the meander by cutting off meander bend 1 and meander bend 2 and creating Wethersfield Cove and Keeney Cove. In addition, the channel east of Wright's Island was cut-off⁹.

The historical data indicates that after this meander cutoff, the channel segment remained relatively straight. While the scroll pattern, for meander bend 2 can be reconciled with the historic event's description, the scroll pattern in meander bend 1 as seen in 1934 aerial (Figure 4.12) is indicative of a slow and steady eastward channel migration, not chute cut off. Therefore this scroll pattern in meander bend 1 had to have been created prior to 1640. Furthermore, the preservation of this scroll patterning indicates that precontact floodplain landforms are capable of being preserved despite two centuries of meander activity and heavy flooding.

Unfortunately, the early, rapid, and urban development of the floodplain (Hartford and Brainard Airport), adjacent meander bend 1 has precluded archaeological survey. The rotation (1683) and emergence of Keeney Cove (1692) means the northern portion of meander bend 2 (East Hartford) does not likely contain evidence of

⁹ Sometime after this event the island was incorporated into the town of Glastonbury, Connecticut est.1690. (Stiles and Adams 1904).

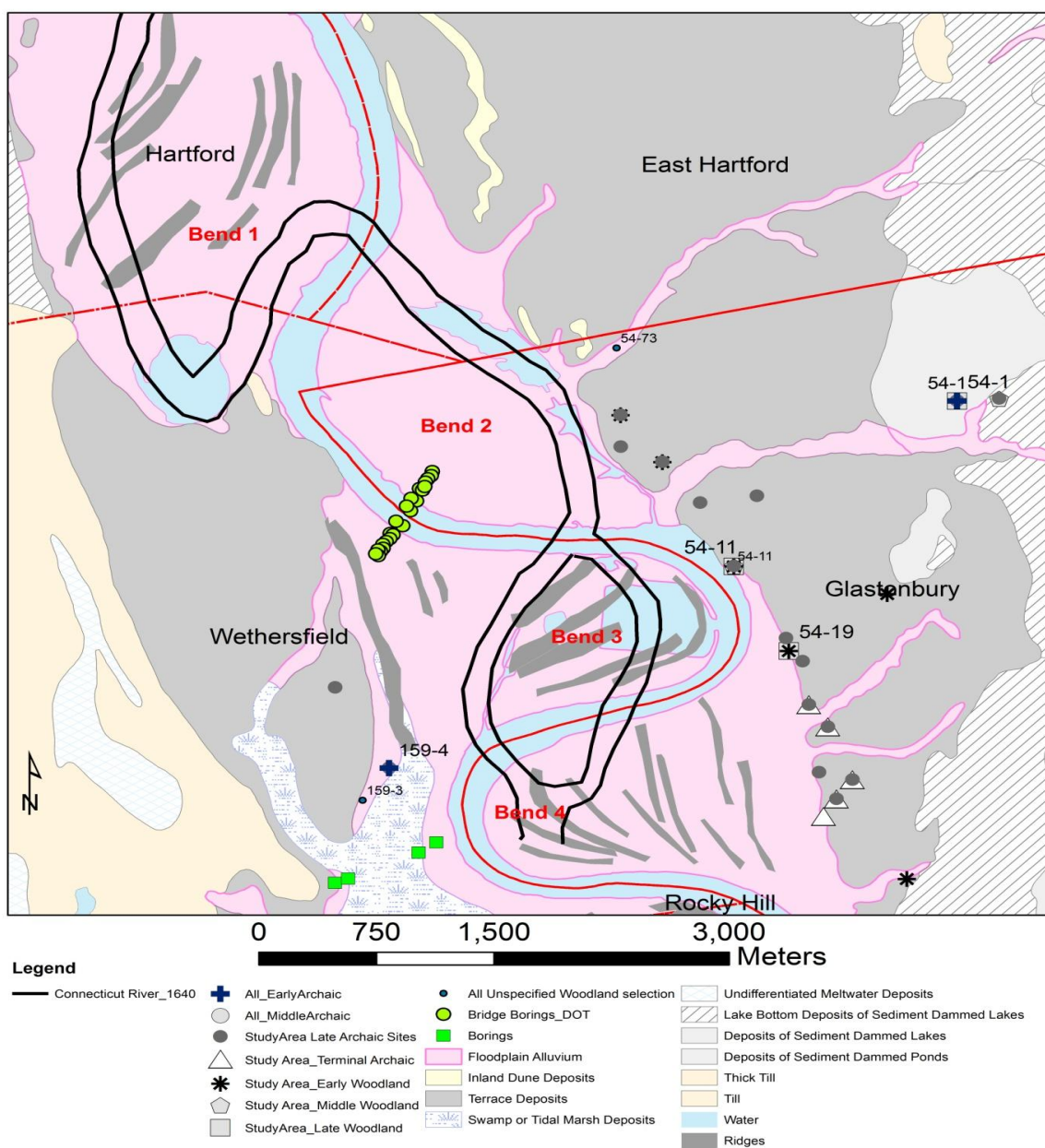


Figure 4.14 Meander Bends 3 and 4. Meander bend 3 contains Crow Point, a remnant of the 1640 channel. The grey denotes the meander scrolls or ridges created as the meander migrates across the floodplain.

This erosion process would have resulted in the loss of any archaeological sites in the migration path of meander bend 3. Meander bend 4 contains mostly floodplain with numerous ridges and swales indicative of a meandering river (Figure 4.14). However, according to the historic maps (19th century meander formation from a straight river) the erosion should be limited to the most western portion of this floodplain.

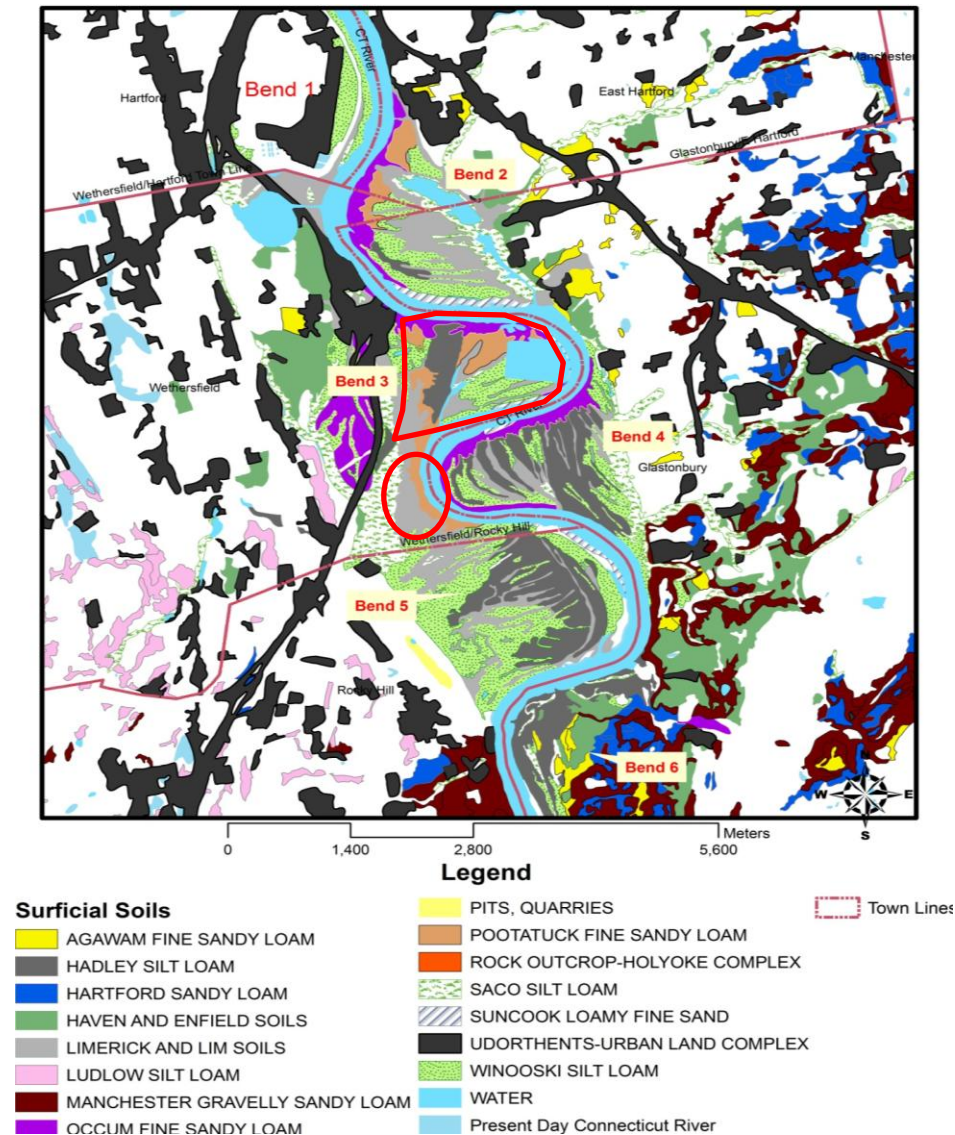
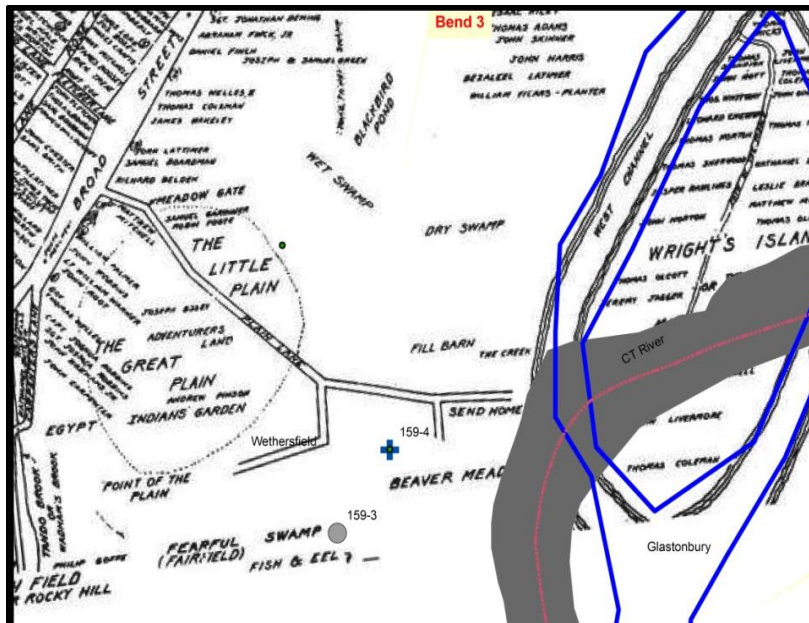


Figure 4.15 Soils Map showing ridge and swale topography

Upon examining the surficial soils map in figure 4.15 it is clear that all ridge and swale topography that is in meander bend 4 is comprised of different soils. The soils closest to the present day river are Occum Fine Sandy Loam and Winooski silt loam. These are the same soil types present in

meander bend 3. The historic maps demonstrate that the Occum Fine Sandy Loam and Winooski silt loam were deposited in the 19th century. Thus it seems likely that in

meander bend 4 the soils closest the present day river were also deposited in the 19th century should also be Occum Fine Sandy Loam and Winooski silt. However, the soil types at the farther edge of the floodplain of meander bend 4 are Hadley and Limerick and Lim soils. The different soils indicate different deposition/migration events that occurred at different times. The Occum Fine Sandy Loam and Winooski Silt are interpreted to indicate migration that occurred after 1640AD (most likely in the 19th Century). The presence of Hadley or Limerick and Lim soils are interpreted to be



4.16 Stiles and Adams rendering of “Ancient Wethersfield” overlaid with archaeological site distribution (1640 map courtesy of Wethersfield Historical Society).

indicative of Pre-contact deposition events.

The meander bend 4 floodplain (east of the river) in Glastonbury remains to be surveyed and may contain archaeological sites in the areas dominated by Hadley or Limerick and Lim Soils. The west bank of meander bend 4

(Wethersfield) is mostly dominated by pond/marsh that were not impacted by the historically documented and present migration of this meander into Wethersfield. Two archaeological sites (159-4 and 159-3) have been identified in this pond/marsh locale (Figure 4.17). Site 159-4 consisted of a surface collection of diagnostic artifacts (bifurcates, vosburg, brewerton, narrow-stemmed points). These Early Archaic to Late Archaic diagnostics were spread over a 3km² area located less than 60m from a present

day pond (Beaver Pond) and 385m from the present day river (Jackson 1940). Site 159-3 contained an Archaic and Woodland component. This narrow floodplain coincides (taking into account cartographic and digitization error) with the area marked as “Egypt Indian Gardens” on Stiles and Adams and rendering of “Ancient Wethersfield” and may contain additional evidence of precontact settlements (Figure 4.16).

Historic Planform Dynamics and Archaeological Site Distribution (Bends 5–6)

The historic maps are limited in detail for this last meander. Nevertheless, from the descriptions of the aftermath of historic flooding events as well as the geological data it can be assumed that the historic flood events had little impact in this portion of the reach. Any impact it did have resulted in deposition in meander bends 5 and 6.

The presence of Hadley silt loam and Limerick and Lim soils with the Late Woodland site, 119-12 supports the conclusion that these areas did not erode as a result of historic meander migrations (Figure 4.17). Therefore these areas have high archaeological preservation potential. While a large number of archaeological sites have been discovered (Figure 4.17), the statistical analysis (chapter 2) completed in Chapter 2 shows that the number of Late and Terminal Archaic sites in the valley is much lower than expected. It was believed that flooding and/ or historic meander migrations explained this discrepancy. However, now that the historic planform dynamics have been fully delineated it is clear that neither flooding nor the historic meander migrations alone are responsible for this pattern. Therefore, any patterns that exist in this distribution were created by the inhabitants themselves or the precontact planform dynamics. Reconstructing the precontact planform dynamics will allow for diachronic analysis of these settlement patterns.

4.5 Summary and Conclusion

Historic planform analysis (1638–present) revealed that the current stable meander morphology is a direct product of only 150 years of downward and westward meander

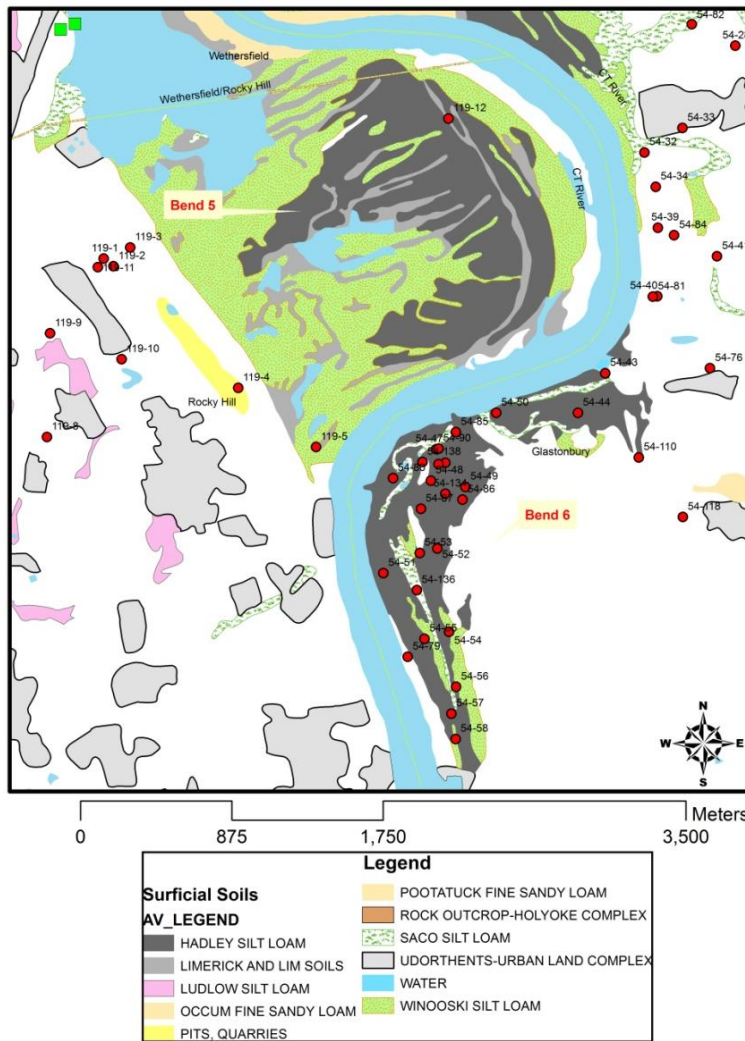


Figure 4.17 Archaeological site distribution of meander bends 5/6.

reach, meander bend 3, and 4, are relatively unconstrained but the top and bottom of the reach, meander bends 1, 2, 5 and 6, are somewhat constrained in their movements. Using these geological constraints the historic planform analysis identified rates of migration and change. The Glastonbury Reach appears to maintain a certain morphological type for approximately 100–150 years. From 1938–1800 the channel

migration. These planform changes took place in a singular meander belt due to the geological constraints, basin geomorphology, as well as previous channel morphology. The constraints and elements directing the reaches evolution are a basalt ridge line at the southern tip of the reach, glacial deposits that inhibit meander development, the slope of the basin, as well as changes to the discharge and sediment loads.

These factors have created a scenario where the middle of the

had a meander morphology; from 1800–1700 the reach had a straight channel morphology; prior to the 18th century the reach had an anabranching morphology. Furthermore, it was revealed that historic meander migration rates average approximately 3.5 meters a year. Therefore, it would take bends 1 and 2 approximately 125 years to migrate across the eastern section of the valley and bends 3 and 4 would take twice as long to migrate across their roughly 3 kilometer wide valley. However, this pattern also indicates that meander bends 1, 2 migrate at half the rate of meander bends 3, and 4. In addition, meander bends 5 and 6 which are constrained by the terrace in Glastonbury and the basalt rock ridge migrate at even slower rates than meanders 1 and 2. Furthermore, it is possible that the middle meander (meander bends 3 and 4) are controlled by the movements of meander bends 1, 2, 5 and 6.

By examining the archaeological site distribution with the reconstructed historic planforms, as well as digital elevation models, and surficial soils it is clear that the majority of sites located on the floodplain are located on the ridge and scroll topography that was created prior to 1640 A.D (Figure 4.12). Although historic meander migrations have eroded much of the floodplain in the upper portion of the reach (Wethersfield and East Hartford), it is clear that the lower portion (meander bends 4, 5, and 6) of the reach were not eroded by the historic meander migrations or flood events. Therefore, the settlement patterns within meander bends 5 and 6, specifically the sites located on ridges, were the remnants of settlement patterns created by the inhabitants.

The coring and sediment analysis undertaken in Chapter 5 is used to reconstruct the precontact planform dynamics to determine their impact on the archaeological site distribution.

CHAPTER 5

Methods: Coring and Grain Size Analysis

5.1 Introduction

Floodplain emergence and change is a reflection of prevailing environmental conditions and changes in those conditions. Sediments and soils that form the floodplain are the traces of this evolution. They indicate the average river hydrology at certain points in time and in specific locales. The sedimentary record can also mark the occurrence of low frequency alluvial events, such as floods, channel shifts, and the expansion of backswamps. The dynamics of the alluvial landscape must be investigated before the context of settlement and can be understood. This chapter presents the geoarchaeological investigation of the Glastonbury Reach's floodplain sediments and stratigraphy.

This chapter begins with a description of the preliminary GIS analysis necessary to identify ideal coring locales. Logistics of fieldwork, equipment description, and the grain size distribution procedures are summarized before presenting the results of the sediment analysis from the Connecticut River study area. The last section presents an interpretation of the stratigraphic record examining possible relationships between the grain size distributions to hydraulic properties and alluvial floodplain landforms.

5.2 Coring: Locale Selection

The Glastonbury Reach of the Central Connecticut River Valley was chosen as the study area because documentation of its recent planform history is relatively abundant. This written record of the channel's changing morphology provides us with a framework that can help gauge the reach's processes and responses to inputs. This framework was used to guide coring activities in several ways. The historic planform analysis (Chapter 4)

demonstrates that the majority of erosion in the last 300 years appears to be concentrated in the upper portion of the reach (meander bends 1-3; Wethersfield and East Hartford, Connecticut) so the coring transect had to be located south of meander bend 3. To gauge how far apart the boreholes should be placed, descriptions and maps of the river were used to calculate the average width of channel so that borehole locations could be spaced accordingly. Finally, the potential transects themselves were chosen based on the likelihood of coring in at least one of the channels depicted in historical renderings.

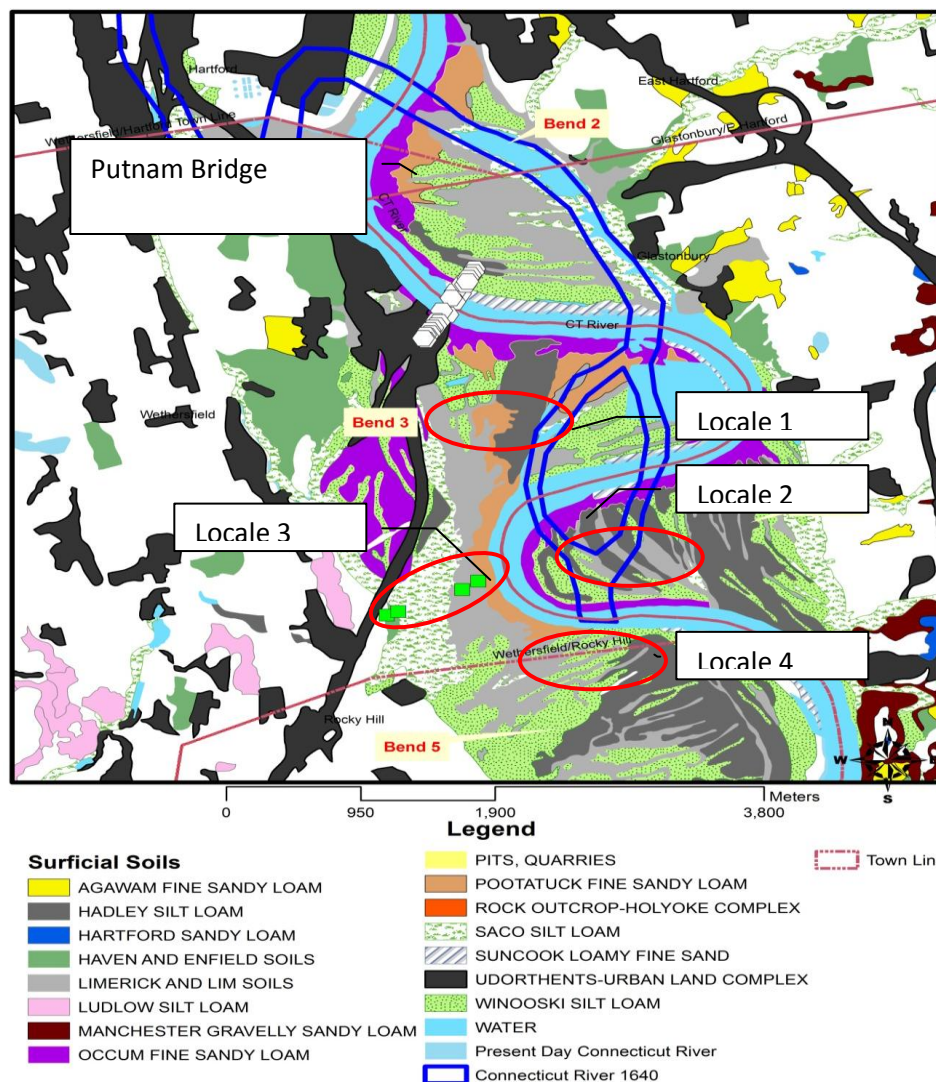
5.3 Coring: Logistics

Coring for subsurface investigations is an economical and effective way to determine the character and depth of sedimentary deposits and buried paleosols and to establish stratigraphic relationships among the deposits (Stein 1986; Mandel 1992). Since a core is a minimally disturbed section of subsurface material it is less destructive and time-consuming than typical archaeological shovel test pits or excavation. A core is defined as a continuous section of sediment obtained by using a hollow cylinder called a corer or coring device. Its use in archaeological investigations began in the 1930's and has continued and developed with the use of coring to reconstruct the environmental context of an archaeological site (Stein 1985). The goal of this dissertation's coring program was to better understand the emergence and creation of the alluvial landscape. Therefore, several possible testing locales were identified for their potential to answer questions related to landform creation, channel location, and planform change such as:

- Is it possible to locate a former channel as indicated in historical maps?
- Is it possible to identify a locale that remained untouched by planform movements of the past 400 years?
- Is it possible to identify a paleosol on a floodplain or terrace?

- Is it possible to locate artifacts from an already identified archeological site with coring technology?

The ideal coring locales were considered to be areas that would yield the most data on the evolutionary history (Figure 5.1). Locales 1 and 2 were considered ideal because of the potential to identify historic in channel deposits and because of the presence of Limerick and Lim and Hadley soils. Locale 3 was ideal because of the high possibility of



encountering evidence precontact occupation. However, the historic maps indicate that there was no chance of sampling any historic in channel deposits. Locale 4 was considered ideal because of the chance of identifying previous in channel deposits,

as well as the presence of Limerick and Lim and Hadley soils but there is not likely any chance for archaeological preservation. Ultimately, the selection of an east/west

transect was constrained by permission from property owners. However, many large land owners, including farmers, the town of Wethersfield, and the Great Meadows

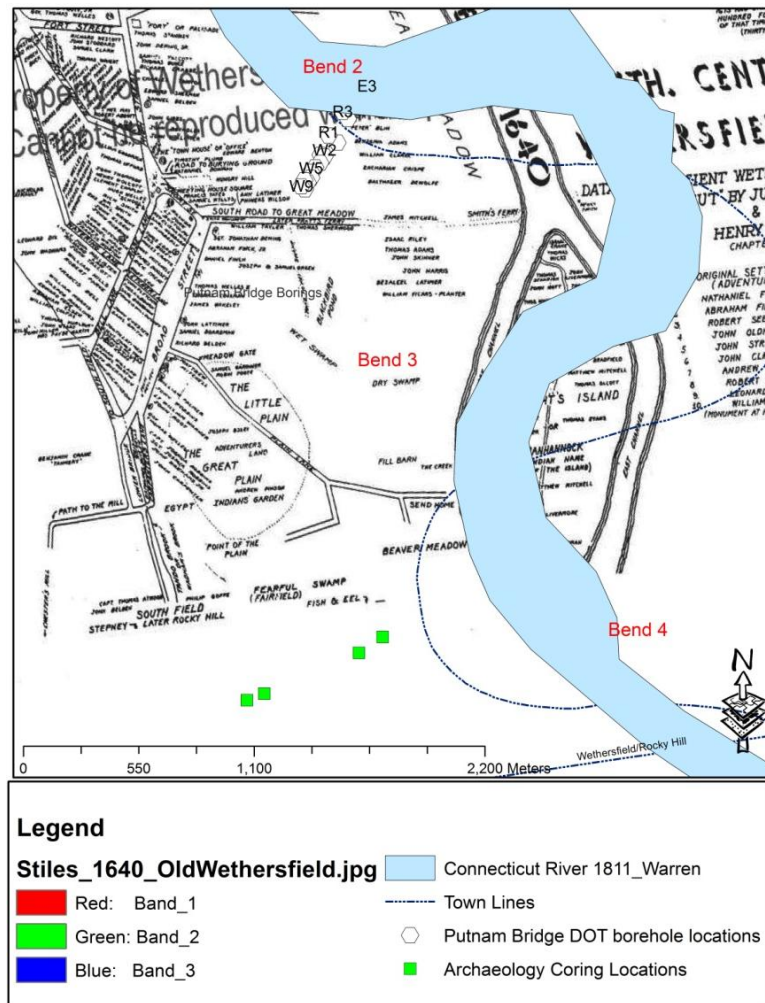


Figure 5.2 Coring transect located just south of “Indians’ Garden” as depicted in map of ‘Ancient Wethersfield’ . Also note the location of the DOT borings and the 1811 channel, as depicted in the Warren map.

Conservation Group, granted permission to core their large tracts of land in locale 3.

Coring locale 3 is located just out of the area called “Egypt Indian’s Garden” in Stiles and Adams rendering of “Ancient Wethersfield” around 1640 (Figure 5.2).

The objectives of the coring and sediment analysis were to: classify the sediment within a core, identify similarities in sediment and stratigraphy among the cores, and for the purpose of

correlation date any organic material identified. Nanson’s (1980) and Allen’s (1965) vertical profile models were used to interpret stratigraphic sections in cores. The interpretation of sedimentary deposits and the surficial geologic record was challenging because despite the demonstrated links between vertical sequences and channel pattern, sequences are by no means unambiguously predictive (Allen 1964; Miall 1977; Bridge 1995; Bristow 1996; Jacobsen, Connor, Oguchi 2003: 24). Nevertheless, the potential to

gain contextual information that can constrain our settlement predictions makes this type of investigation necessary. For comparison data this dissertation also examined the borehole drawings from the Connecticut Department of Transportation 1957 Putnam Memorial Bridge Engineering project (Figure 5.1).

According to georeferenced 19th century maps the channel migrated to the Putnam Bridge area in 1811. By comparing and contrasting the cores from the two coring locales additional questions may be addressed. A hydraulic corer from the University of Connecticut's Environmental Research Institute (ERI) was used to extract cores. The Geoprobe percussion hammer mounted track vehicle of the 66 Series was chosen for the fieldwork. The hydraulically-powered direct push machine can extract 9 to 18 m (30–60ft) of continuous cores. The boreholes were placed approximately 125 meters apart, about half the width of the Connecticut River. Fieldwork took 4 days to set up and 3 days to core with 4 people operating machinery, directing coring locales, labeling cores, and recording observable data. By the end of fieldwork four boreholes had been cored to an average depth of 7 meters.

The first borehole (CTR₁) was located closest to the river in Limerick and Lim alluvial and floodplain soils. At 5 meters a water logged gray clay was encountered. Due to the depth and the amount of water the sediment began slipping out of the core liner. The second borehole (CTR₂) was also located in Limerick and Lim soils on the edge of a sparse reed meadow, just east of the beaver pond; therefore the meadow itself was quite wet. At 8 m depth the front of the track mounted hammer began sinking into the muddy meadow. The third and fourth boreholes (CTR₃ and CTR₄) were located over 700 m from the river and were both taken from a slightly higher elevation than the floodplain with CTR₃ overlooking the western edge of the beaver pond. The surficial

soils, at CTR 3 and CTR4 were Saco Silt loam and Broadbrook Silt Loams, respectively. Saco Silt loam is a floodplain soil, but BroadBrook is a non-hydric prime farmland soil.

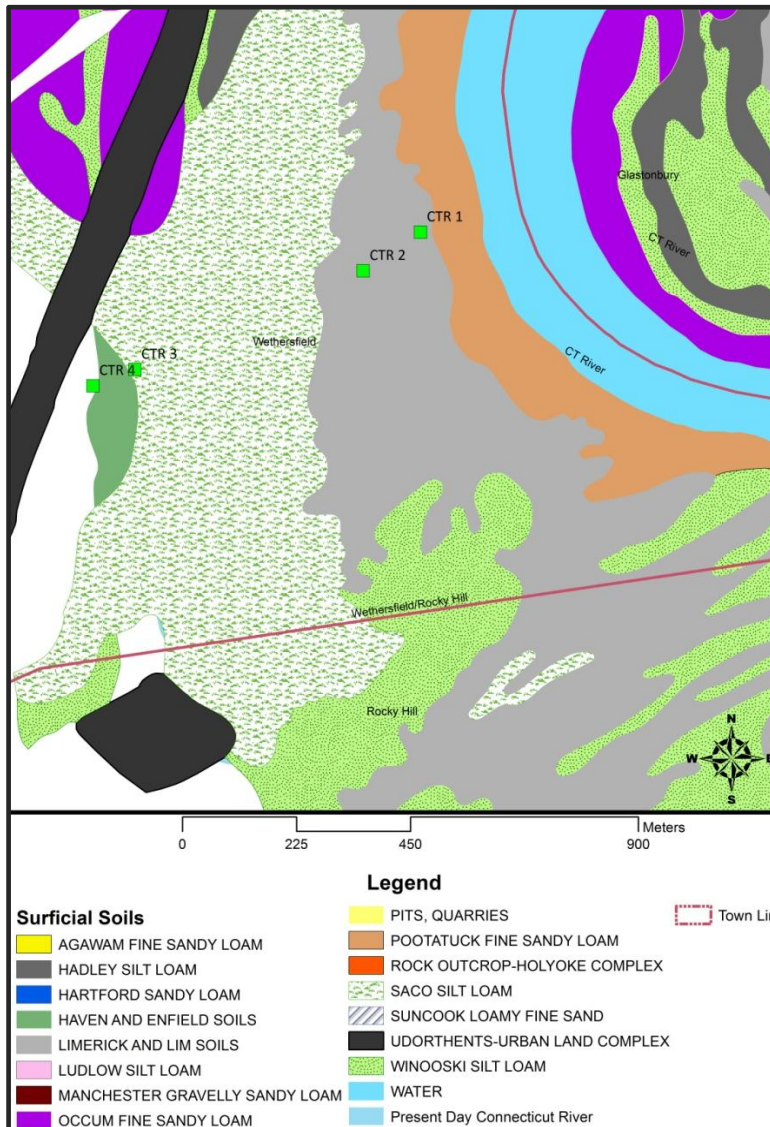


Figure 5.3 Individual boreholes labeled and referred to in text as: CTR1, CTR2, CTR3, and CTR4.

5.4 Laboratory Methods and Results

The cores that were extracted were split open and the sediment analyzed using the standard sieve and pipette methods (Lewis and McConchie 1994b). Texture is one of the most important characteristics of a stratigraphic profile. The variation in texture can be used to decipher the geomorphic history of a landform. Standard sieve tests provide the basis for determining frequency of particle size occurrence

(histograms), grain size distribution (cumulative weight percent curves), and other statistical and hydraulic property measures to assist in determining the energy of the deposition. Grain size separation analysis took over 4 months to complete. To save time no samples were measured from strata that consisted mostly of mud, had little to

no stratigraphy, or did not contain organic matter. Prior to weighing samples organics were removed from cores. Only cores 1 and 2 contained organic material. These samples were sent to Beta Analytic for AMS radiocarbon dating (Table 5.2). Samples were placed in a nest of eight-inch diameter sieves ranging from -1 to 4.25 *phi* (2-.053mm). All fractions were weighted to .01. The weights were cumulated, and the cumulative percentages were derived from the cumulated weights. Due to inadequate number of sieves and the length of time needed to clean and dry the sieves after each sample, a decision was made to alter the nest arrangement. During data analysis this resulted in inability to directly compare samples' grain size so one nesting scale had to be adopted and all fractions were shifted to conform to that scale. Also fractions requiring pipette analysis were not weighed due to the length of time required to perform the analysis and this author's inability to dry (without baking) and weigh the small fractions. Cumulative percentages, without clay, were then plotted against *phi* diameter (*Phi*^ϕ is one useful and commonly used way of representing grain size information for a sediment distribution) in Excel. The cumulative percent frequency distribution curves represent the cumulative weight by particle size of the sample (Appendix 1). In the cumulative weight percent passing curve, the fraction that is finer than each subsequent grain size is shown. In the other curve, the cumulative weight percent retained, the fraction that is coarser than each subsequent grain size is shown. Based on these distribution curves, the sediment mode, median, mean, and standard deviation is calculated for all samples (Table 5.1).

Sample (m)	CTR 1a 1m	CTR 1b 5.5m	CTR 2a 5.5m	CTR 2b 5.8m	CTR 2c 6m	CTR 2d 7.3m	CTR 2e 7.34	CTR 2f 7.5m	CTR 2g 7.5m	CTR 2h 7.9m	CTR 2i 8.2m	CTR 3 5m	CTR 4a 1.3m	CTR 4b 6m
Mode (phi)	3.5	.5	2.5	3.5	3.5	3.5	1.5	3.5	1.5	2.5	2.5	7	2.5	7
Median (phi)	3.5	2.5	3.8	3.8	2.3	2.5	1	1.5	1.5	2	1.8	6	2.5	6.2
Mean (phi)	3.4	3	3.4	3.4	2.4	2.6	1.2	1.5	1.5	1.8	2.6	5.5	2.5	6
Standard Deviation (phi)	.43	.31	.38	.38	.5	.5	.38	.5	.5	.62	.63	.75	.58	.75

Table 5.1 Average sediment size for all fractions (CTR1-4)

Location: Core and UTM coordinates	Elevation (mbls)	General Lithofacies	Material	¹⁴ C yr B.P.	Lab Number
CTR1 18/696442/4618336	2.92	low stage-slackwater	wood	1,183 ± 48	Arizona AMS AA91138
CTR1 18/696442/4618336	3.07	low stage-slackwater	wood	2,147 ± 43	Arizona AMS AA91140
CTR1 18/696442/4618336	3.17	low stage-slackwater	wood	2,127 ± 43	Arizona AMS AA91139
CTR1 18/696442/4618336	3.66	floodplain paleosol	wood	2,459 ± 44	Arizona AMS AA91135
CTR2 18/696329/4618260	1.82	floodplain paleosol	wood	1,137 ± 50	Arizona AMS AA91137
CTR2 18/696329/4618260	2.62	low stage-slackwater	wood	2,192 ± 48	Arizona AMS AA90958
CTR2 18/696329/4618260	2.68	low stage-slackwater	wood	2,422 ± 45	Arizona AMS AA90956
CTR2 18/696329/4618260	2.74	low stage-slackwater	wood	2,367 ± 45	Arizona AMS AA90957

Table 5.2 Radiocarbon dates from Glastonbury Reach, Wethersfield Connecticut

Using the grain size analysis the stratigraphy of the cores was drawn and labeled accordingly, using the Udden - Wentworth grain size classification (Figure 5.4-5.8)¹⁰.

Using radiocarbon dates and stratigraphic profiles CTR 1 and CTR 2 could be correlated with each other (Figures 5.4 and 5.5).

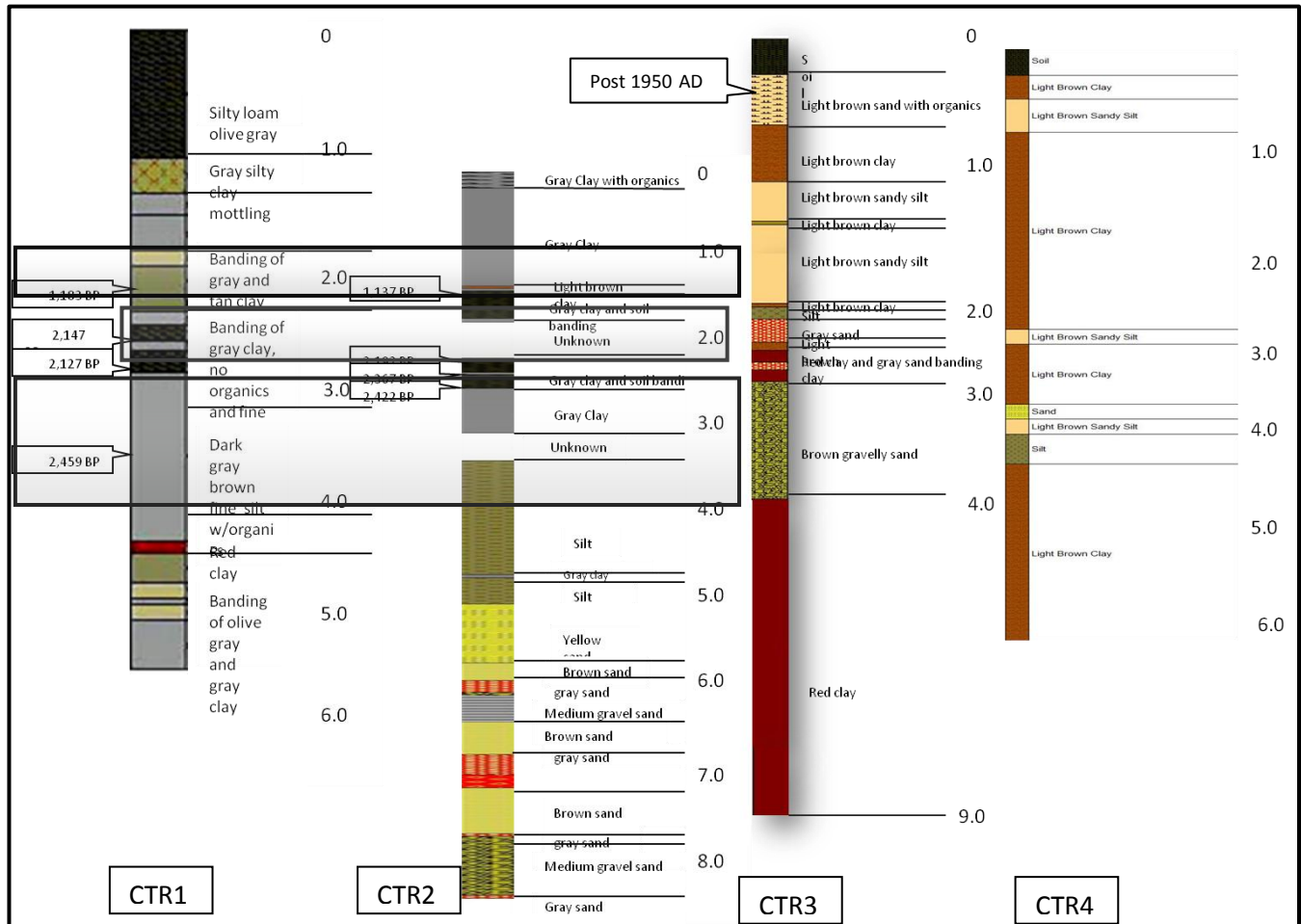


Figure 5.4 Stratigraphic sections from cores (CTR1-CTR4) . Numbers to left of core represent depth in meters. Cores CTR1 and CTR2 could be correlated with each other based on radiocarbon dates and matching stratigraphy.

¹⁰ Typically the Wentworth limit of gravel is ϕ , in this particular sediment the significant size break occurs much lower, therefore 0ϕ was used as the gravel limit.

Character of Sediment

Nanson (1980) and Allen's (1965) vertical profile models are used to interpret the character of the sediment and stratigraphic profiles. CTR 1 (Figures 5.3, 5.4 5.5) was extracted, on the east bank, 100m from the current river (Figure 5.2). Its sediments consist of well sorted coarse sand silt and clay with the sand/silt specimen mean of 3.2ϕ . Approximately 6 meters below surface sediment is dark waterlogged grey clay. Gleying and then silty clay with organics may be indicative of static or slow moving water. This strata also contained woody organic material that was dated to 2500BP. The sediments in the top 3 meters of the core CTR1 are similar to the sediments from the 2-4m section of core CTR2 (Figures 5.4-5.6).

CTR2 (Figure 5.7) was extracted approximately 200m west of the present day river. Presently, the floodplain location from which this core was extracted feature is a sparsely vegetated floodplain that is very wet (geoprobe track sunk half a meter into the ground while extracting hammering and extracting core). At the 4-8 meter mark of the core CTR2, the stratigraphy begins to differ from that of CTR1 (Figures 5.5, 5.6). This stratigraphy is comprised of small layers of silt, sand, and gravel. These strata consists of sediments that fines upwards but, at the 3 meter mark (2422 B.P.) banding of greenish grey clay with and without organics begins. The woody organic material was radiocarbon dated to 2422 B.P. Values for kurtosis and skewness were calculated for samples taken from this core show that CTR 2 sediments consist of a strongly bimodal mixture of gravel (0ϕ), sand (2.3ϕ - 3ϕ) and coarse silt (4ϕ). Nevertheless, prior to 2500BP there is no evidence in the sediments (gleying) of any standing water. The fining upward cycle, as well as the bimodal mixture of sediment, and the non-normal kurtosis of samples from this core indicates this area was once a low energy landscape

element. Therefore, this environment is interpreted as former bar (point bars, alternating, transverse). This alluvial landscape element is created by the deposition of gravel, sand, then silt (Folk and Ward 1956: 25). The upward fining sequence is interpreted as sedimentary evidence of a relict floodplain landscape element. The sediments of CTR 3 (Figure 5.8) and CTR4 (Figure 5.9) are mostly silt and clay with some gravel. The clays are light brown and red in color indicating aerobic activity but no organics were identified below the 1 meter mark. Due to its higher elevation (1 m above floodplain) it is believed that the CTR3 and CTR4 locale was always a low energy depositional environment.

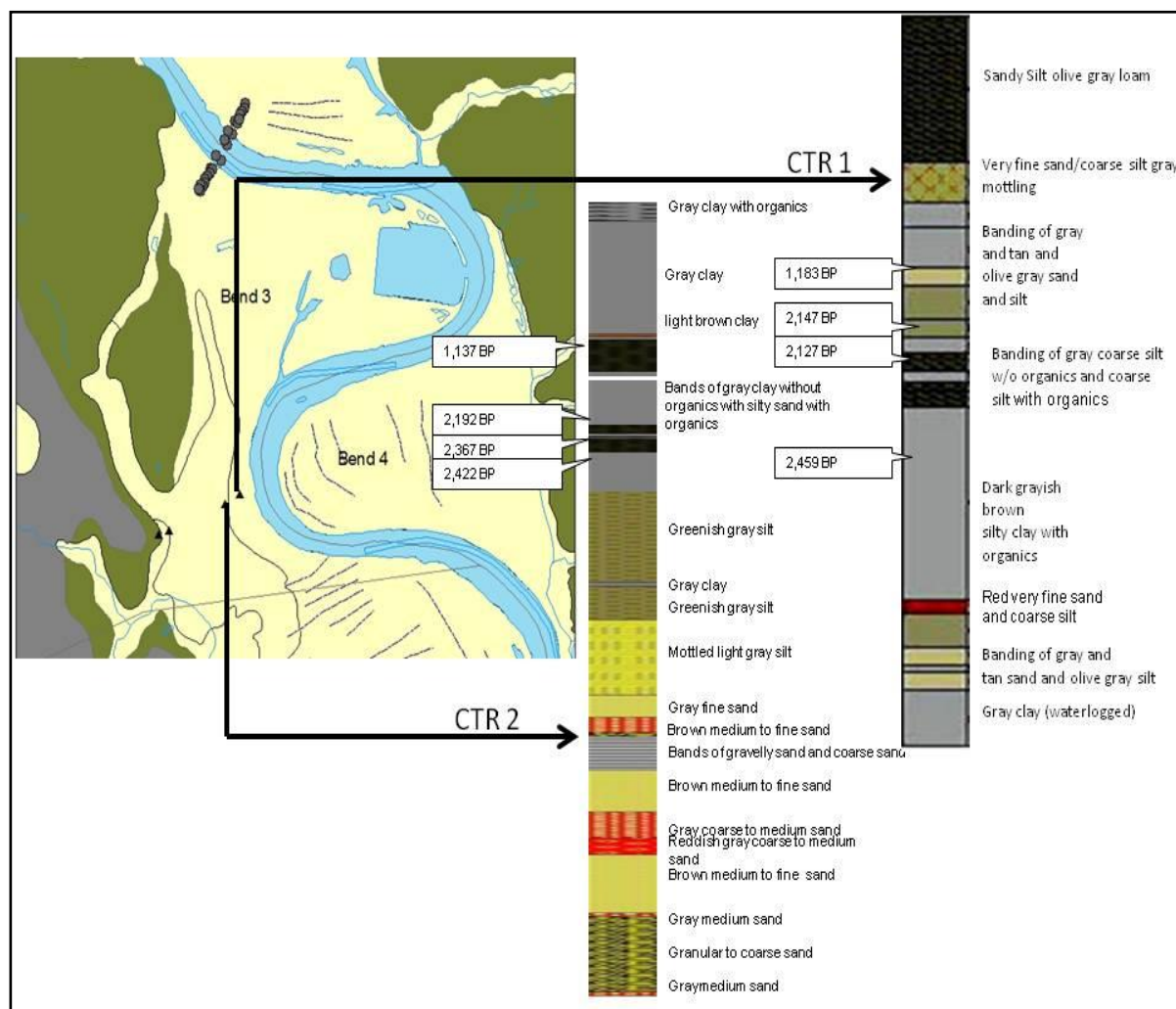


Figure 5.5 Locations of CTR and CTR2. The top portion of CTR and CTR 2 stratigraphic profiles correspond well with one another indicated they were subject to the same deposition events.

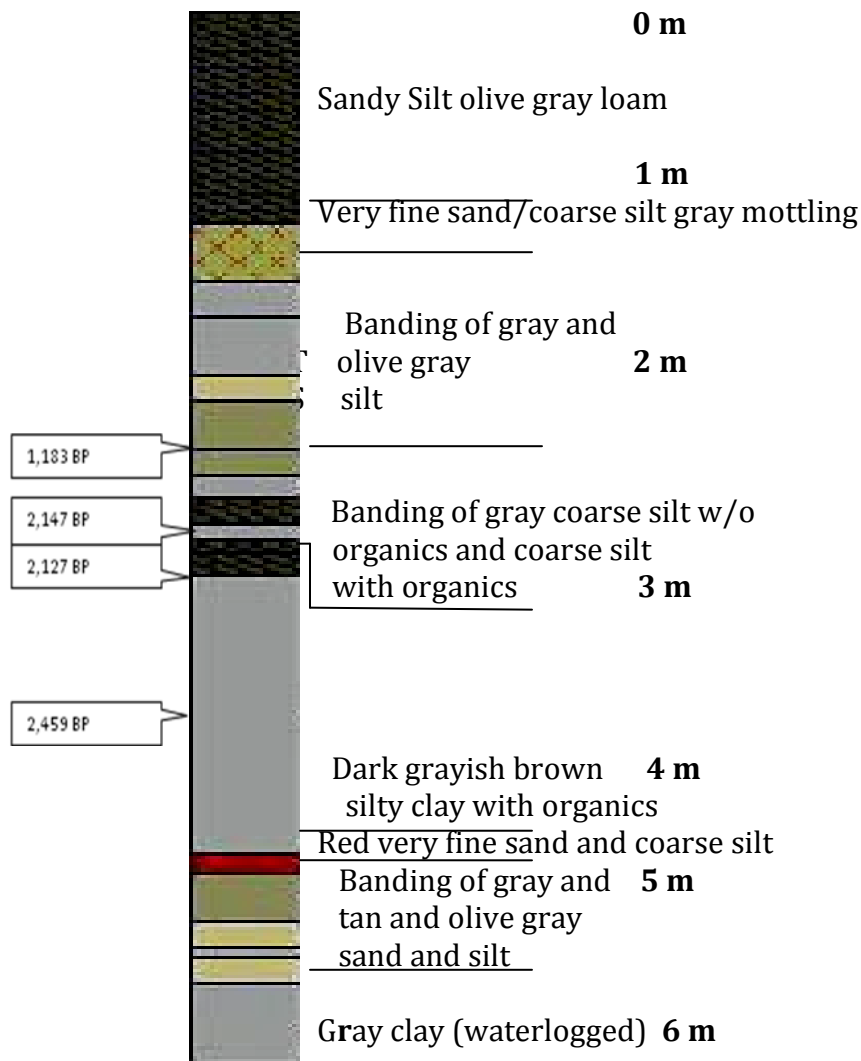


Figure 5.6 CTR1 0-6 m (0-20') : The stratigraphy of CTR 1 extracted, on the east bank, 130 m from the current river. The banding of gray silt coarse silt with organics indicates flooding followed by stable floodplain (2-4m) This section dates to 2459 BP 1183 BP. The red very fine sand layer gray clay may be the beginning of waterlogged soils draining. The waterlogged grey clay is indicative of slow moving/"lacustrine" water.

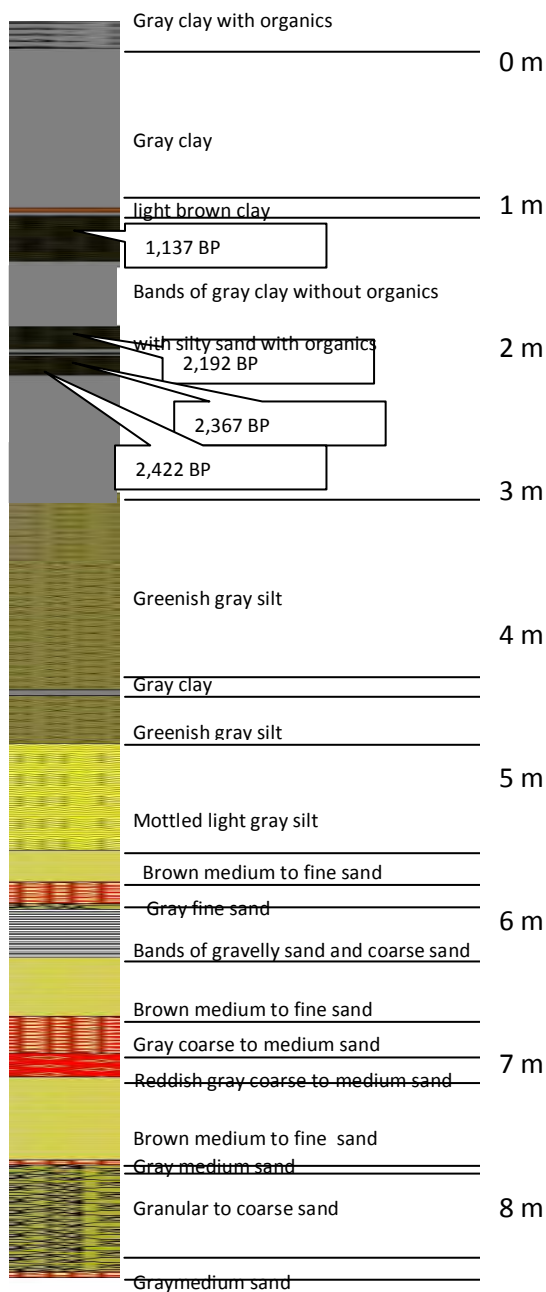


Figure 5.7 CTR2: 9 m (0-30 ft) The second core was extracted 200 m from the present day river. CTR2 is comprised of thin layers of silt, sand, and gravel. These strata consists of sediments that fines upwards. This fining upward is interpreted as a point bar formation. At the 3 meter mark banding of greenish grey clay with and without organics begins. The start of this woody organic and point bar formation began around 2422 B.P.

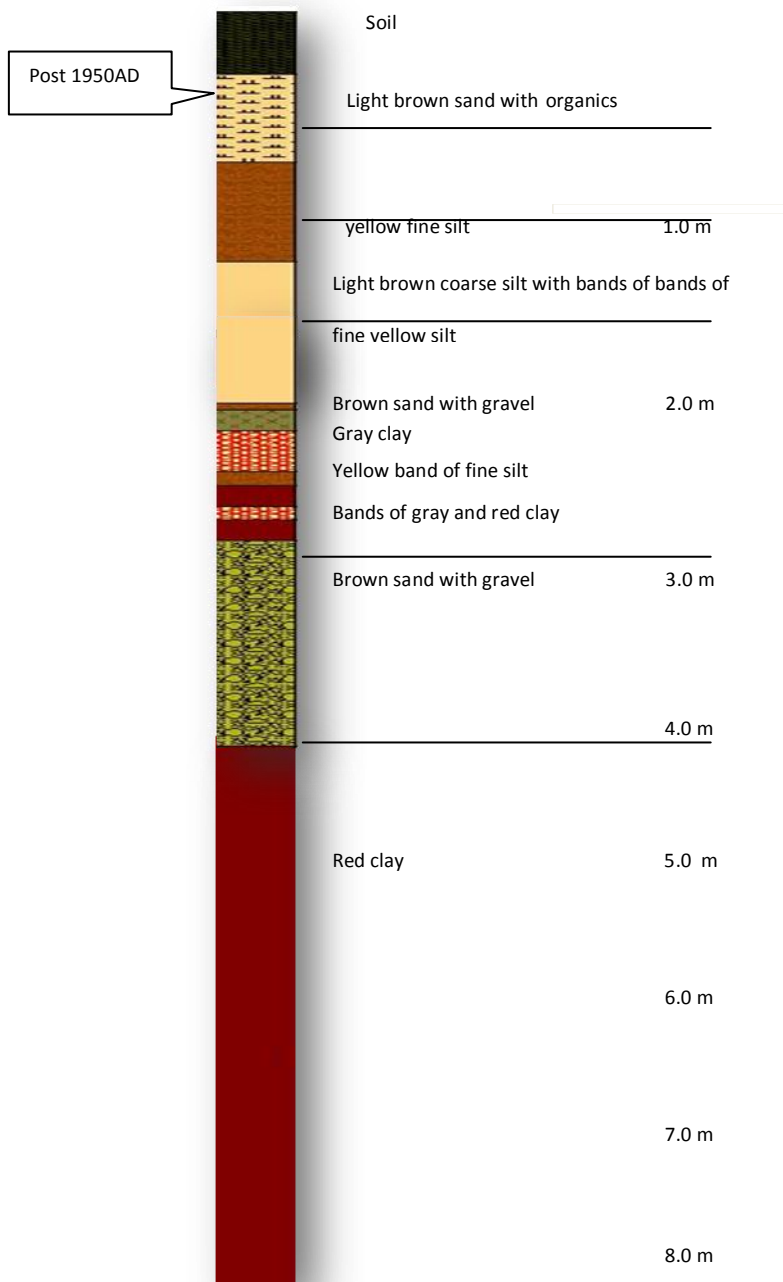


Figure 5.8: CTR3 went to a depth of 8 m . The core was extracted 750m from the present day river. The stratigraphic profile is completely different from CTR and CTR2. It is interpreted to be a depositional environment by overbank flooding – dominated by sediments created by the waxing and waning of the adjacent beaver pond as well as flooding (hydraulic ponding) from the river.

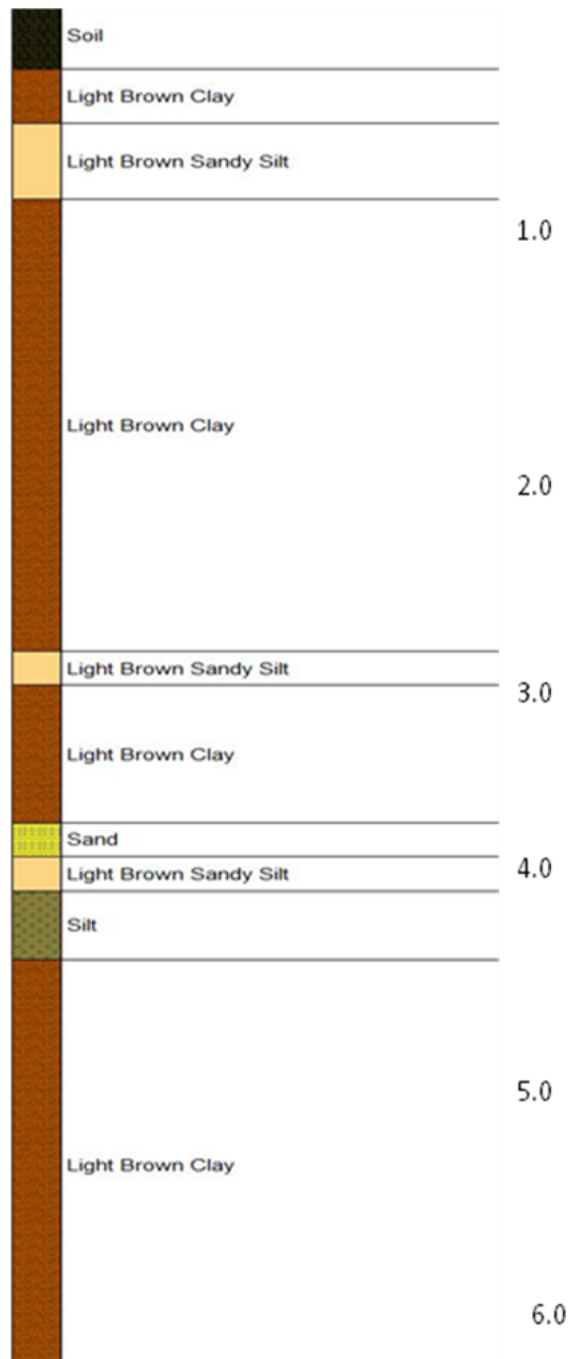


Figure 5.9: CTR4 was extracted 850 m from the present day river. It is mostly comprised of alternating layers of light brown clay and light brown sandy silt. Although close to CTR3 its this cores strata indicate another depositional environment.

5.5 Comparison to Putnam Bridge Borings

The cores extracted in preparation for the construction of Putnam Bridge were bored approximately 2500 m north (Figure 5.1) of this study's transect locale. The site and boring plan shows 23 borings were extracted, 10 from the west bank of the present channel (W); 6 from the present channel(R); 7 from the east bank of the present channel (E)(Appendix 1). The stratigraphy in these core drawings are compared to the stratigraphy from this study's cores. All DOT borings went to bedrock, approximately 35-40 meters (120-140 ft) below ground level. The drawings indicate that the fine brown sand and silt that makes up the river bottom also comprises the first 6 meters (20 feet) of the east and west banks. Below the fine brown sand silt layer there is a brown or red brown clay layer in all the borings of the west bank. However, R6, E2, E3, E4 and E7 have grey clay at the same approximate depth. The borings taken from the present channel all have a hardpan layer directly above the bedrock which may indicate that hardpan is an indicator of the initial stream channel or glacial lake. On the east bank, only the E4 boring contained hardpan overlaying bedrock. In contrast, four of the borings on the west bank, W10, W8, W7, W5, contained hardpan that directly overlay bedrock. The other west bank borings had gravel, boulders, or a combination of gravel and boulders at the same approximate level.

Since this dissertation's cores went to 6-8 meters below ground, direct comparisons at this depth only will be made. The sediments of the cores extracted from the South Collected Wethersfield borings are quite different than the Putnam Bridge Borings. The Putnam Bridge borings, from the west bank appear to be comprised of overbank deposits. This phenomena is supported by the research of Thorson et al.

(2014) which indicates that where the river is constricted in lateral migrations the floodplain is dominated by overbank deposits.

The east bank borings extracted from the Keeney Cove were similar to CTR1 and CTR 2 in that they also had large amounts of grey clay in E2, E3, E4 and E7. It is plausible that the grey clay, which is in CTR1 without organics and CTR2 with organics, is an indicative of a marshy environment that existed around 2000BP. However, the fact that the grey clays in CTR1 and CTR2 were encountered at 4-6 m mark and the Putnam Bridge grey clays were encountered at 12–25 m indicates that the floodplain area of CTR1 and CTR2 are not subject to as much overbank deposition as the rest of the CRAL.

5.6 Summary and Conclusion

Using historical writings, drawings and maps of the Connecticut River Wethersfield, Glastonbury, and Rocky Hill a 2.5km transect was selected to identify historic and Pre-contact channels, identify alluvial deposits, locate destroyed and intact areas, and determine if sediments indicate buried landscapes (Guccione 1993; Gladfelter 1985). With coring completed, grain size analysis was used to decipher the geomorphic history. Grain-size analysis is necessary to identify buried alluvial deposits such as point bars, alluvial fans, and palaeochannel (Lowe and Walker 1984; Gladfelter 1985; Stein 1985; Farrell 1987; Bridge et al.1995). The presence of gleyed sediments that change to clayey sediments with high organic content in CTR1 are interpreted to indicate that CTR1 sampled a pre-contact channel locale. Also upward fining sediments and bimodality identified in CTR2 were identified in CTR2 and interpreted as evidence of a point bar. The data from CTR1 and CTR2 indicates that the river was located much farther west than its present day location sometime around 2500 B.P. The sediments of CTR3 and

CTR4 revealed that this area has a completely different depositional environment. The locale of these two cores area appears to be a remnant terrace that may contain deeply buried archaeological deposits.

Results of this sediment analysis were compared with previously extracted borings just 2 kilometers north of the South Wethersfield transect. Sediments and stratigraphy from the 0-8 meter range at the Putnam Bridge area were quite different from those taken for this study. While the Putnam Bridge borings appeared to represent mostly overbank deposits the sediments from this dissertation's transect were much different than the bed load of the river thereby, indicating mostly lateral accretion in the transect area. This stratigraphic data will be used along with results of the historical planform analysis (Chapter 4), to reconstruct the precontact planforms and provide a context for settlement and preservation of archaeological sites in the Glastonbury Reach.

Chapter 6

Planform Reconstruction for Settlement Pattern Analysis

6.1 Introduction

The previous chapters have demonstrated that the archaeological distribution has been fragmented by the meander migrations during the Pre-contact period. Specifically in question is the archaeological site distribution in meander bends 4, 5, and 6. To obtain an understanding of how the current archaeological site distribution was created and fragmented this chapter utilizes the stratigraphic data (Chapter 5) to reconstruct the shape and position of the Glastonbury Reach at different points in prehistory. With the shapes and positions identified this chapter then utilizes the constraints and rates of migration identified by the historic planform analysis (Chapter 4) to reconstruct the planform dynamics. These dynamics are examined with the archaeological site distribution to determine how the changes fragmented the archaeological record. The reconstruction of the planform dynamics reveals that archaeological sites with multiple occupations and components located on slightly raised ridges are a product of the settlement systems incorporating the landforms created by past meander migrations.

6.2 Reconstruction of the Pre-Contact Planform

The stratigraphic sections constructed in the previous chapter are utilized to reconstruct the precontact planforms. Since sedimentary sequences are not unambiguously predictive of environment, interpretation of the stratigraphic sections is constrained by the geological history, as well as the geological constraints and surficial geology delineated in chapters 3 and 4. The main assumptions guiding the planform reconstruction are:

- The floodplain was most stable from around 6.4–2.3 ka and 1.0–0.4 ka
- The Hadley and Limerick and Lim soils are indicative of Pre-contact meander migration

- The direction of meander migration is constrained by physiography, (bends 1, 2, 5 and 6)
- Meander evolution is initiated in meander bends 1 and 2
- Meander bends 3 and 4 can migrate across the floodplain.
- During periods of stability the rate of meander migration is consistent with the 19th century rates of meander migration.
- Meanders migrate within the range of 2 to 6 meters/year.

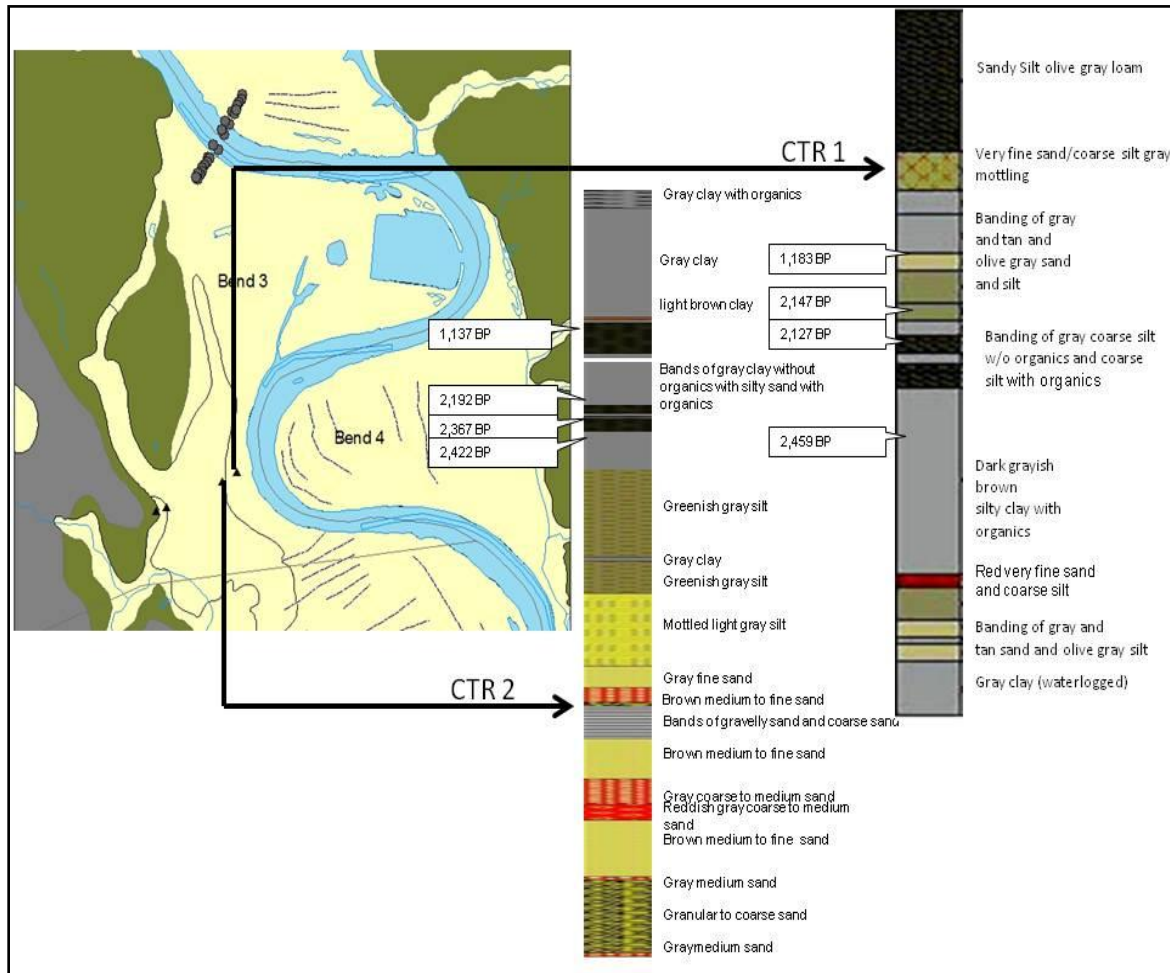


Figure 6.1 CTR and CTR2 stratigraphic sections.

The Pre-contact planform reconstruction begins with the sediment and stratigraphy in CTR1 and CTR2 dated to about 2450 B.P. These deposits are consistent with the sedimentary sequence taken from the terraces in Hartford, Connecticut (Thorson, personal communication; Thorson et. al 2014). The presence of clay and silt as well as organic material indicates that the floodplain was stable and drainage was good enough to allow for the development of a vegetated floodplain. Also in core CTR 2 is a sequence of sediments fining upwards in the strata. This upward fining sequence only exists in CTR 2 and was deposited just before the grayish brown silty clay deposit (2422 B.P.). This sequence of sediments fining upwards is interpreted as indicating the presence of a point bar. Point bars are formed when alluvial sediments are deposited on the inside of a meander bend. Given the presence of this sequence in CTR2 before 2422 B.P., as well the presence of Limerick and Lim soils in this locale it is likely that the Pre-contact channel was located, at least, 300m west of its current position around 2600 B.P (assuming 19thc rates of meander migration). Given that point bars can only be formed on the inside of a meander bend, this meander bend had to have been “c” shaped with its outer bank butting up against a bedrock fault that constrained further westward meander migration (Figure 6.2). Moreover, given the bedrock constraint on this meander, and the presence and shape of the Limerick and Lim soils presently in meander bend 5 it is likely that the Pre-contact channel extended southwards (Figure 6.2). Assuming similar to present day channel widths this would place the majority of the channel in the present day Beaver Pond locale (Figure 6.3) and extending into what is today the Rocky Hill floodplain (presently within meander bend 5). The basalt ridge (Figure 6.3) extending across the river and the town of Rocky Hill would have constrained this meander from migrating any further south or west.

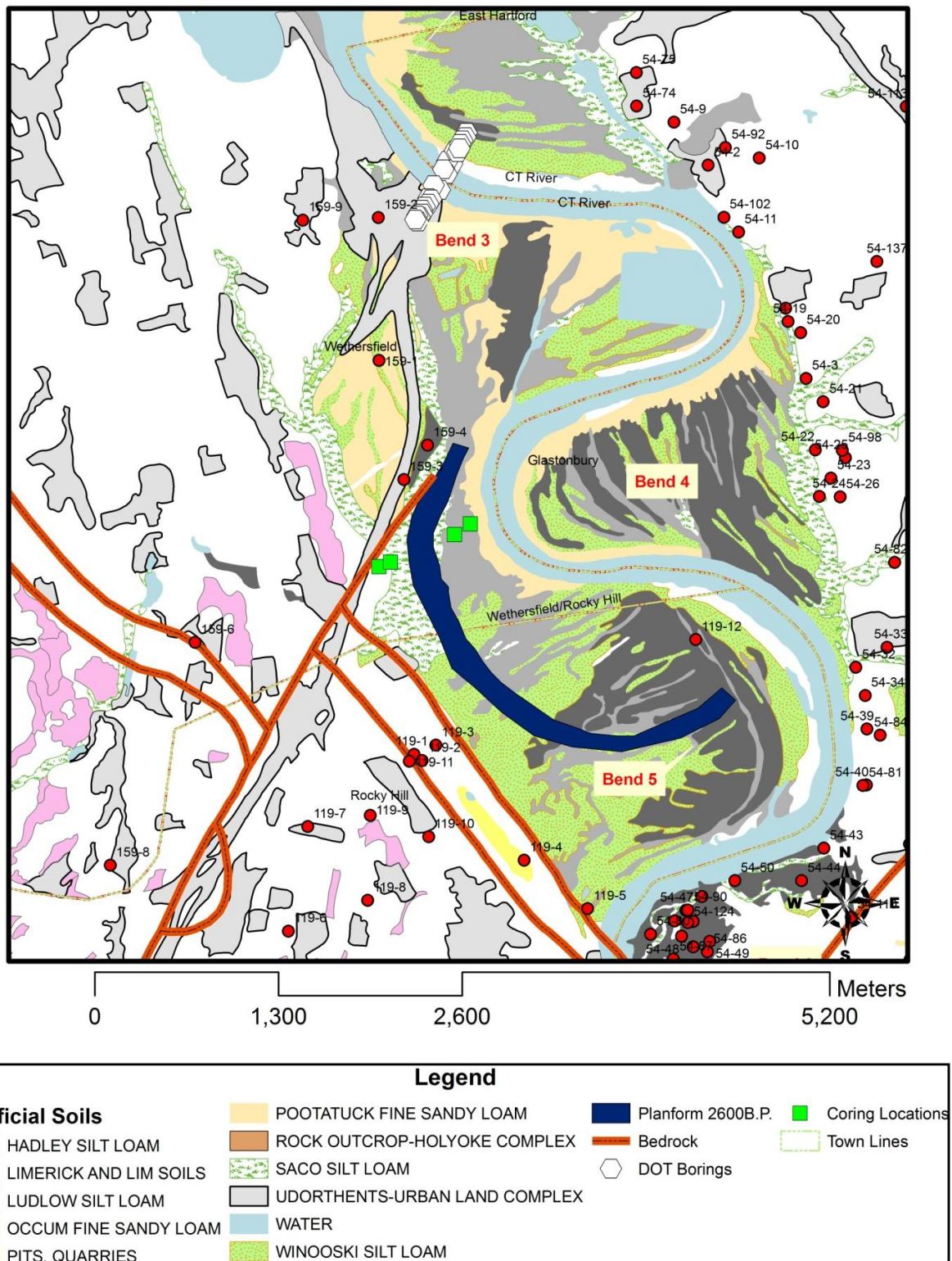


Figure 6.2 Position and shape of meander bend 4 around 2600B.P.

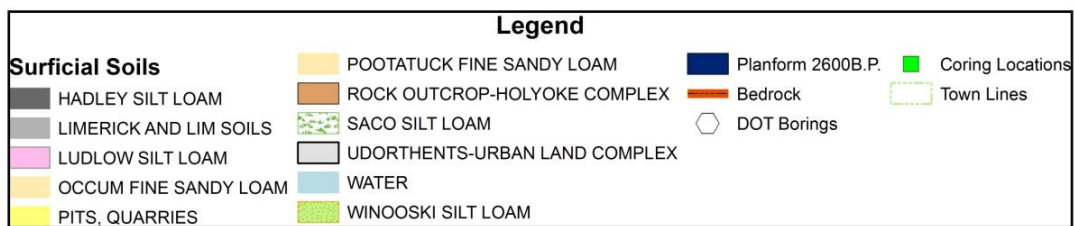
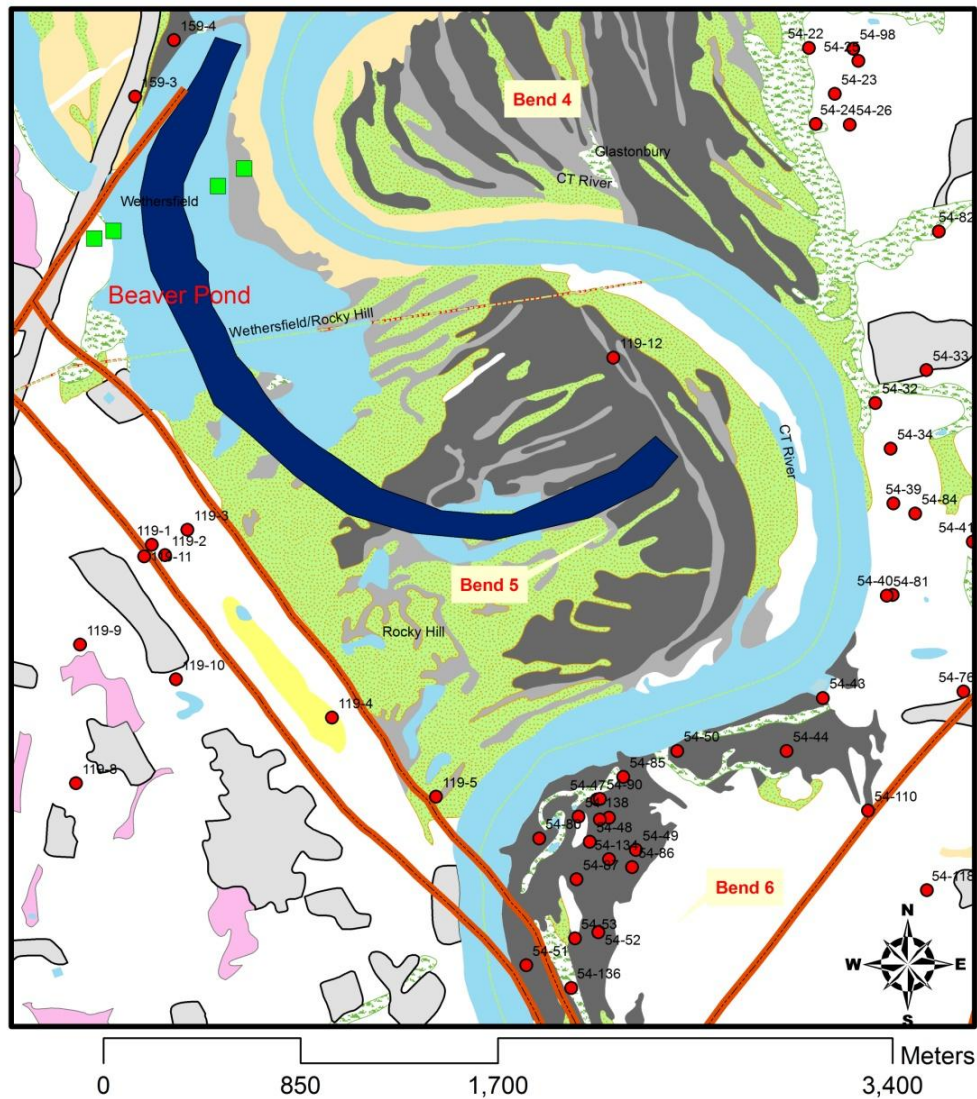


Figure 6.3 The reconstructed planform over the present day Beaver Pond.

Given the geological constraints, namely terrace and bedrock that exists for the southern-most section of the Glastonbury Reach, the last meander (bends 5 and 6) is likely to have had a constricted shape (Figure 6.4). The shape and position of the 2700B.P meander bend 3 cannot currently be known. However, the Jurassic bedrock and the presence of one Early Archaic Period sites (159-4) on a slightly elevated surface, a possible terrace remnant, indicate that meander bend 3 remained east of this locale (Figure 6.4).

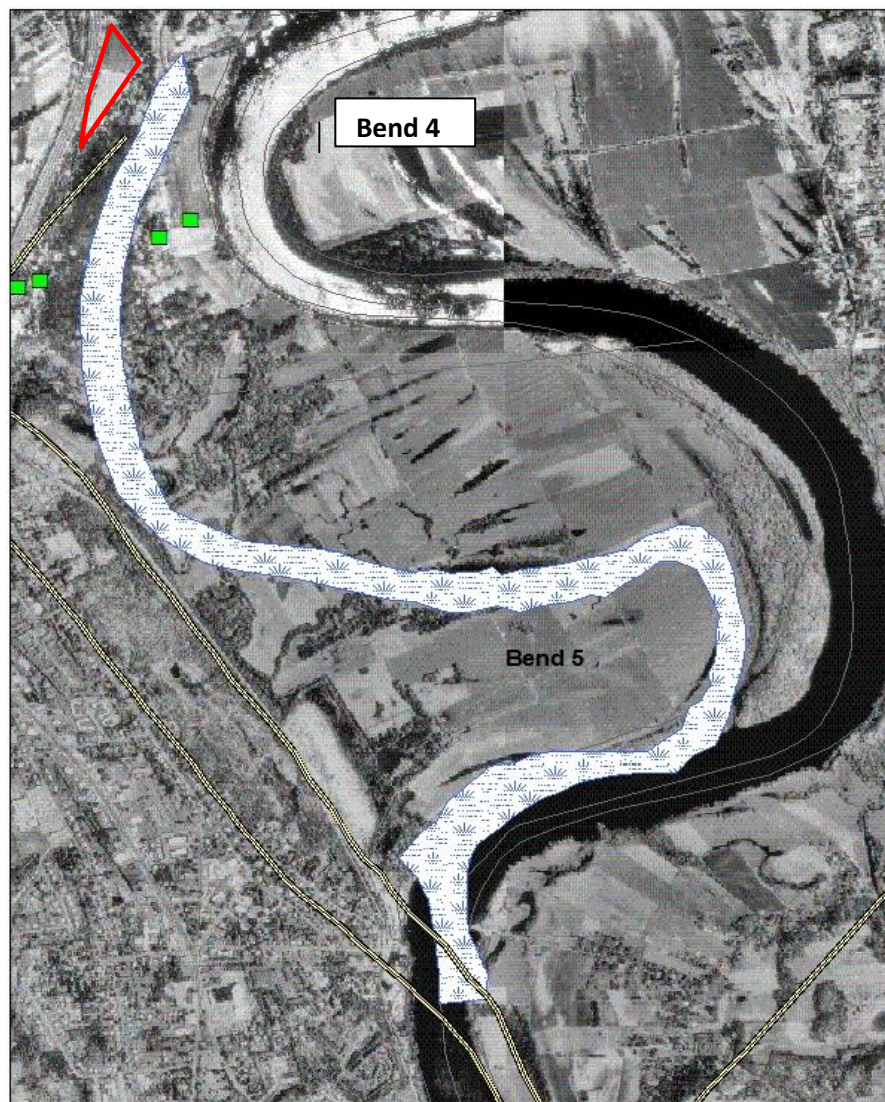


Figure 6.4 The possible meander shape and position of meander bends 4 and 5 (2600B.P) overlaid with the 1934 aerial. The red outline marks the location of two archeological sites located on an elevated surface.

The stratigraphic profile and ridge and swale topography supports this 2600 B.P. planform reconstruction. Moreover, the ridge and swale topography also indicates the direction of meander erosion. Combining an examination of the direction of ridge and swale bend with the 2600B.P. planform reconstruction and the rates of meander migration (established by historic planform dynamics) allows for the reconstruction of planform dynamics that may have occurred prior to and after 2600 B.P.

6.3 Pre-contact Planform Dynamics

Meander migration is erosion which leads to loss of part or all of the archaeological record. Reconstructing the planform dynamics is essential to discovering how the archaeological record has been fragmented. The ridge and swale topography visible in the 1934 aerial photography and represented by Hadley and Limerick and Lim soils in the soils maps are examined in conjunction with the results of the historic planform analysis (Chapter 4) and the 2600B.P reconstruction to determine the pre-contact planform dynamics.

The historic planform analysis demonstrated that the historic meander migrations could not have created the ridge and swale topography on the side of the floodplain in bend 4 and could not have created any of the ridge and swale topography in bend 5. The historic planform analysis also demonstrated that the stable meandering channel migrates at a rate of 2-6 meters/year. With the assumption that this steady migration rate was the same during prehistory the planform dynamics are reconstructed.

The ridge and swale topography indicate that prior to 2600 B.P. meander bend 4 was located in what is today the Glastonbury floodplain. It began to migrate west, into the present day Wethersfield floodplain, until it hit the bedrock constraint at which

point a portion of the meander began to rotate south, into present day Rocky Hill. Therefore, the 2600 B.P. planform emerged due to this earlier migration of bend 4 (Figure 6.5). Assuming a steady meander migration rate of 6m a year, meander bend 4 was located in Glastonbury around 3300 B.P and began migrating west and then south. This steady erosion west and then south would have destroyed any archaeological sites established before 2700B.P. The only site present in this path is the Morgan Site (119-12) a Late Woodland site (A.D. 1170, A.D. 1320, and A.D. 1360). The presence of the site, which occupies the entire length of the ridge, indicates that the channel that created the ridge was east of this position well before A.D. 1170, the date of earliest occupation.

Given the constraints that existed for meander bend 4 and 5 it is highly likely that the 2600 B.P. planform experienced some form of cut off (Figure 6.6). The presence of the crescent shaped beaver pond and the lack of additional ridge and swale topography in meander bend 5 supports this cutoff scenario. If the cutoff occurred in between meander bends 4 and 5 (Figure 6.6) it would have resulted in the creation of an oxbow lake out of the former meander bend 4 (beaver pond). This cutoff scenario is possible if, meander bend 3 was located near its 1640 A.D. planform position (Figure 6.7). The stratigraphy and radiocarbon dates of CTR1 does indicate that this meander was very close to its present day location at about 2100B.P.—1187B.P. Therefore the cutoff and enlargement of meander bend 5 could have occurred anytime within this period.

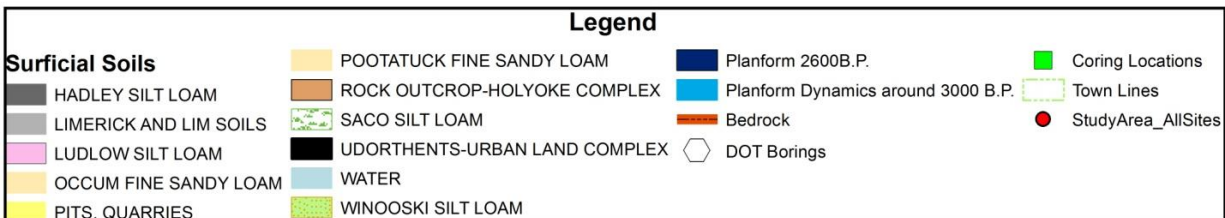
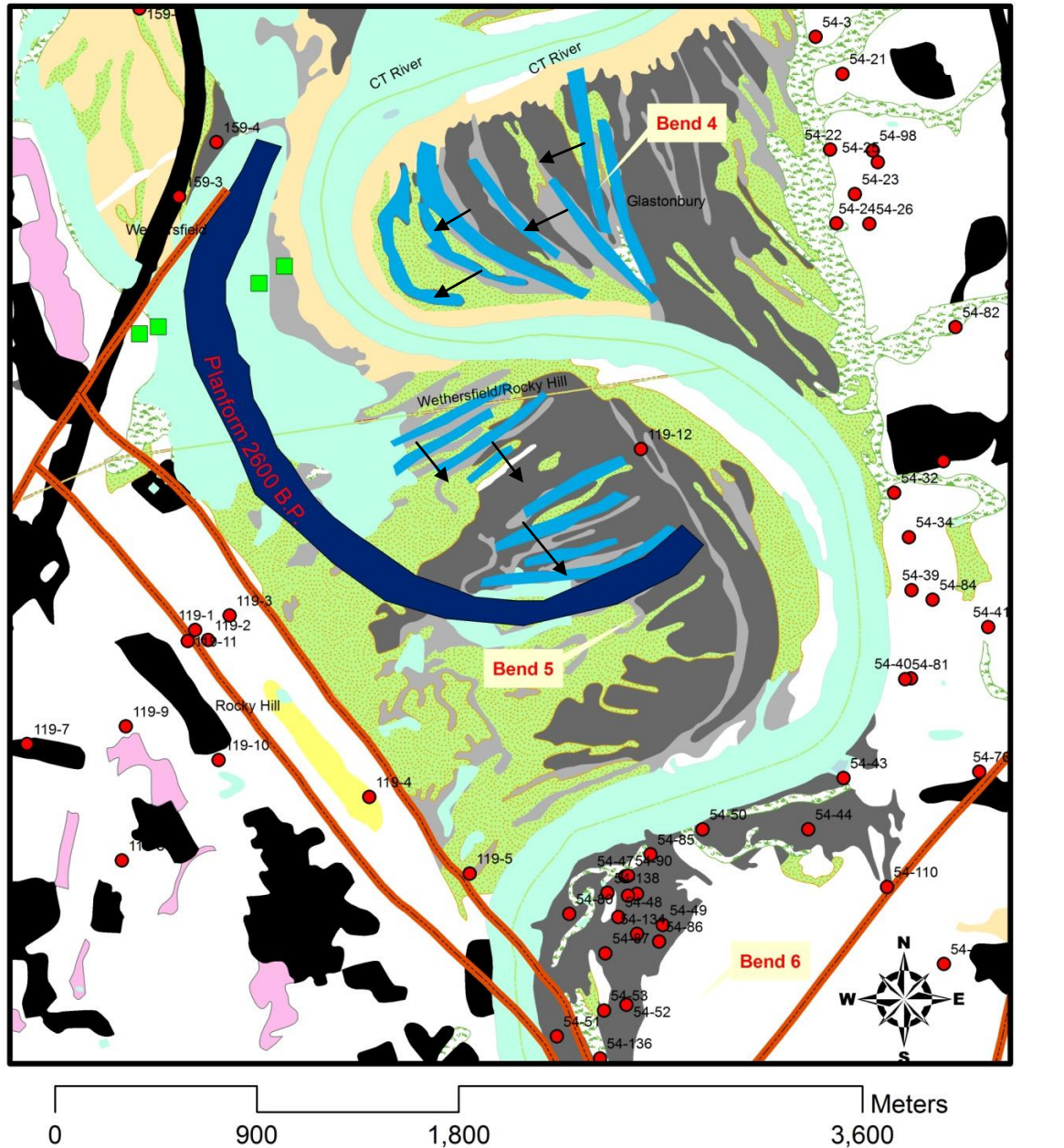


Figure 6.5 Precontact planform dynamics close to 3000 B.P.

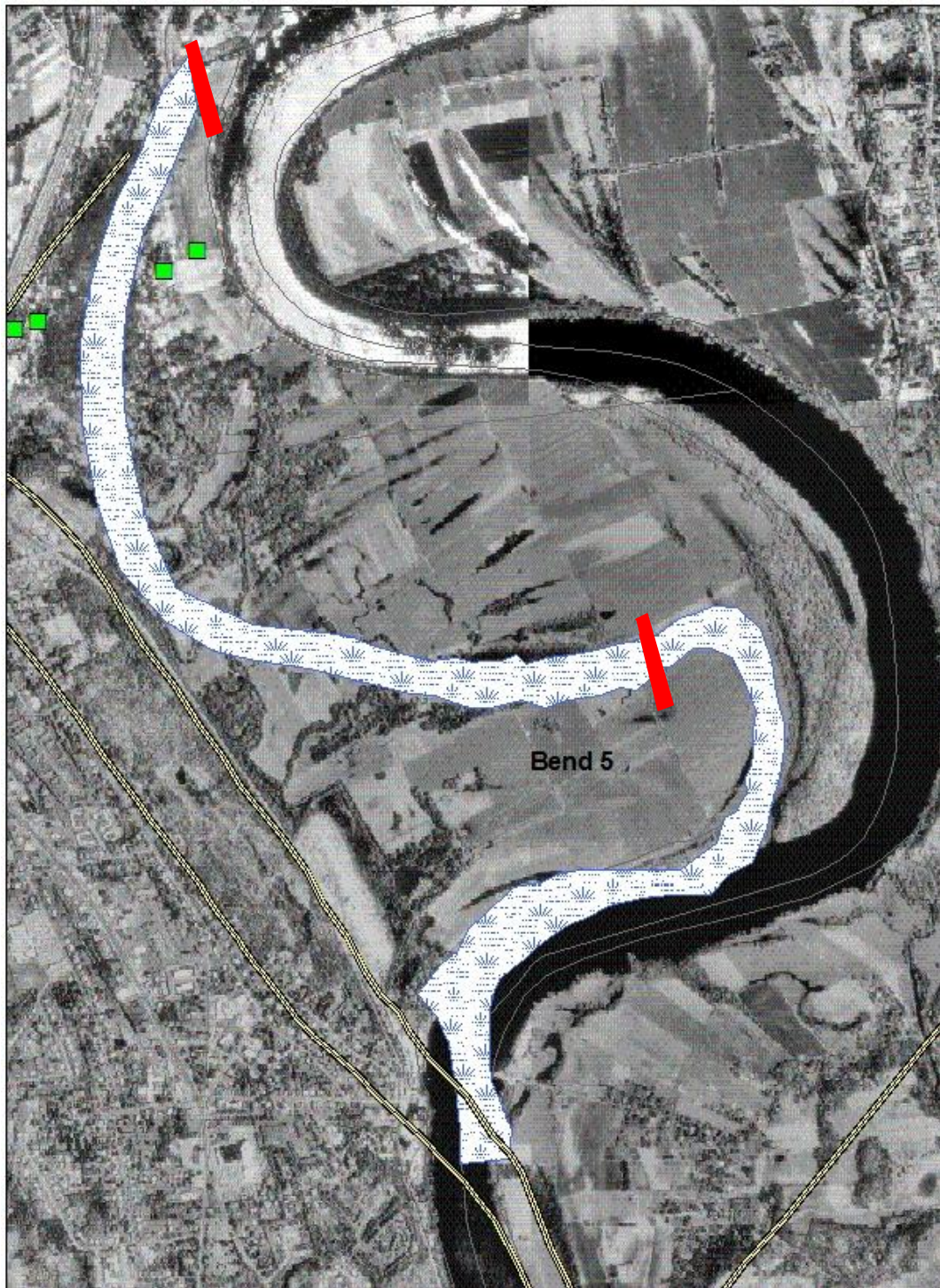


Figure 6.6 Meander bend cutoff. Red lines indicate where cut off may have occurred.

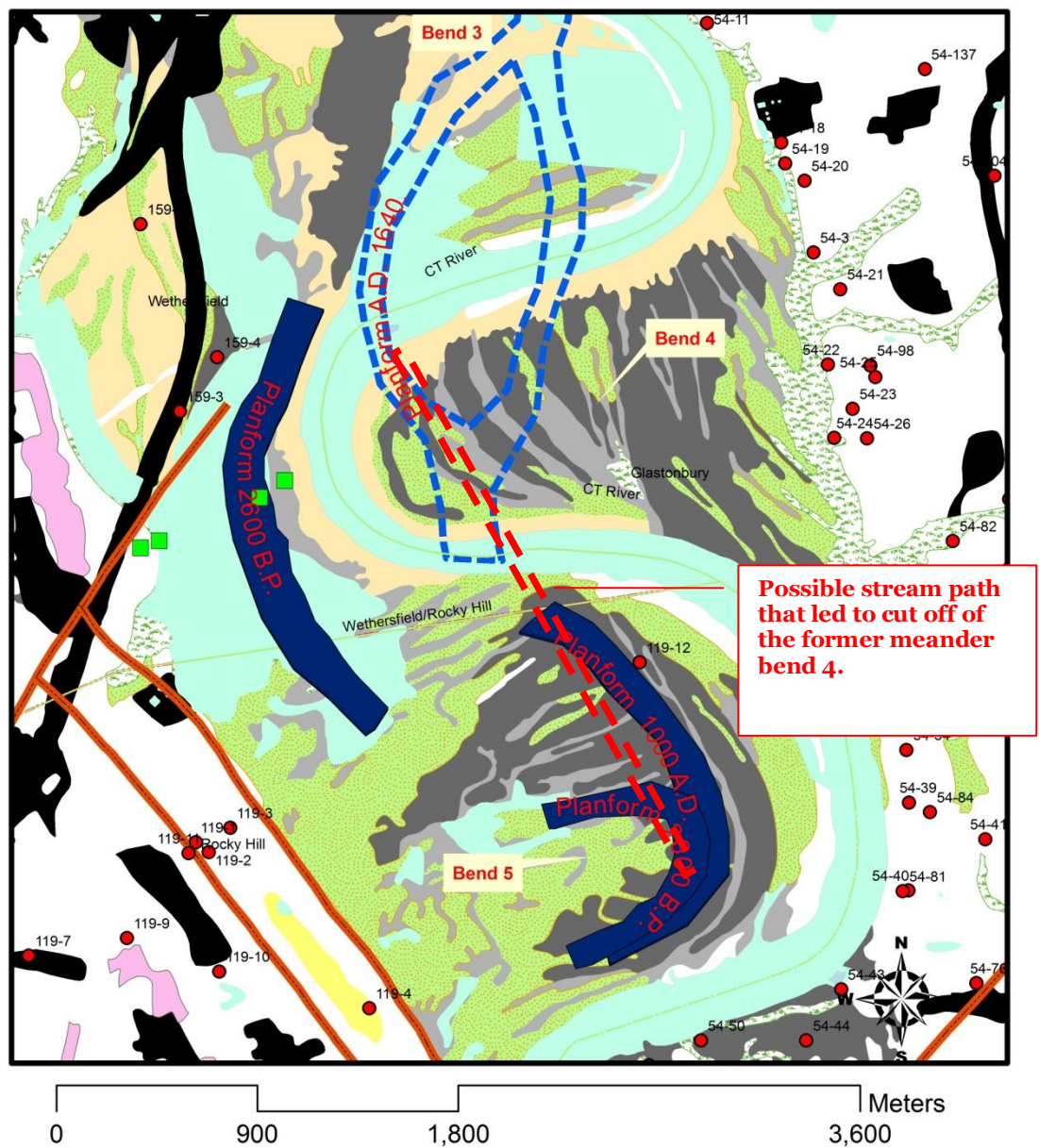


Figure 6.7 Meander bend reconstructions: 2600-2100B.P.; A.D. 1000; A.D.1640

The meander bend 5/6 enlargement to its north and its migration east had to have occurred well before A.D. 1170, the earliest occupation of 119-12. Given a migration rate of 3.5m/year, meander bend 5 may have been half the size of the present day meander around 1900 B.P. (Figure 6.7). The reach north of the hypothesized meanders 4, and, 5 could have been straight, remaining on the western side of the floodplain (*i.e.* left of the Putnam Bridge) or could have meandered along the 17th century Keeney Cove path. However, the stratigraphic sections and historical planform analysis demonstrate that during the Woodland Period (2700 –400B.P.) meander bends 3/4 and 5/6 were located on the western half of the floodplain. In addition, it is likely that during this same time frame the dominant migration pattern for meander bends 3/4, and 5/6 was north and east. With these planform dynamics delineated it is possible to determine how the record may be fragmented because of the precontact meander migration.

6.4 Fragmentation of the Archaeological Record

The planform dynamics indicate that any sites established in meander bends 3, 4, and 5 between 3000B.P. and 1100 B.P. would have been destroyed. This would have resulted in the destruction of any Late Archaic, Terminal Archaic, Early Woodland sites that were established north or east of the constricted meander morphology (Figure 6.7). The only sites that could have survived are those that were created after the migration, or those that remained out of the direct path of migration. Such as the sites 119-12 and 119-5 (Rocky Hill-meander bend 5) and the sites on the floodplain of meander bend 6. Upon examination of the archaeological site distribution and planform dynamics the following patterns are found to be the result of Pre-contact planform dynamics:

- A larger number of Late Archaic components on the east bank compared to the west bank.
- A higher number of Late Archaic sites compared to Terminal Archaic components on the east bank

- A higher number of large Late Woodland residential sites compared to Early Woodland and Middle Woodland residential sites on the west and east bank.

Furthermore, studying the archaeological site distribution with the reconstructed planform dynamics revealed two unexpected patterns:

- there are no large Late Woodland sites on the floodplain east of the river (Glastonbury, CT)
- the vast majority of sites are located on linear ridges that were created after the river migrated

This dissertation demonstrates that these unexpected patterns are the result of settlement choices made by Pre-contact groups.

Archaeological Site Distribution and Planform Dynamics: Bend 4:

The large terrace overlooking the floodplain contains a number of Late Archaic and Terminal Archaic archaeological sites (54-11, 54-18, 54-19, 54-137, 54-19, 54-20, 54-3, 54-21, 54-25, 54-23, 54-24, 54-82). The west bank of this bend (Wethersfield) is dominated by marsh and pond. Reconstruction of the planform dynamics indicate that around 3000 B.P. the river was located within the middle of the meander bend 4 floodplain and began to migrate west (Figure 6.5). These dynamics mean that any site established west of the probable former channel before 3000B.P. was destroyed by this westward migration. Furthermore, the meander began migrating back east around 2600B.P.–A.D. 1640. Therefore, any sites established on this area, during this time period, would also be destroyed. That does leave the eastern most area of the present-day floodplain within meander bend 4 intact and likely to contain Late Archaic archaeological sites. On the west bank of meander bend 4 the only area capable of having archaeological sites (159-3, 159-4) is a triangular shaped 11 acre area, approximately 10m above the rest of the floodplain and also located behind the bedrock fault line (Figure 6.8). It is unclear if the elevation above the rest of floodplain or the bedrock has allowed for site preservation.

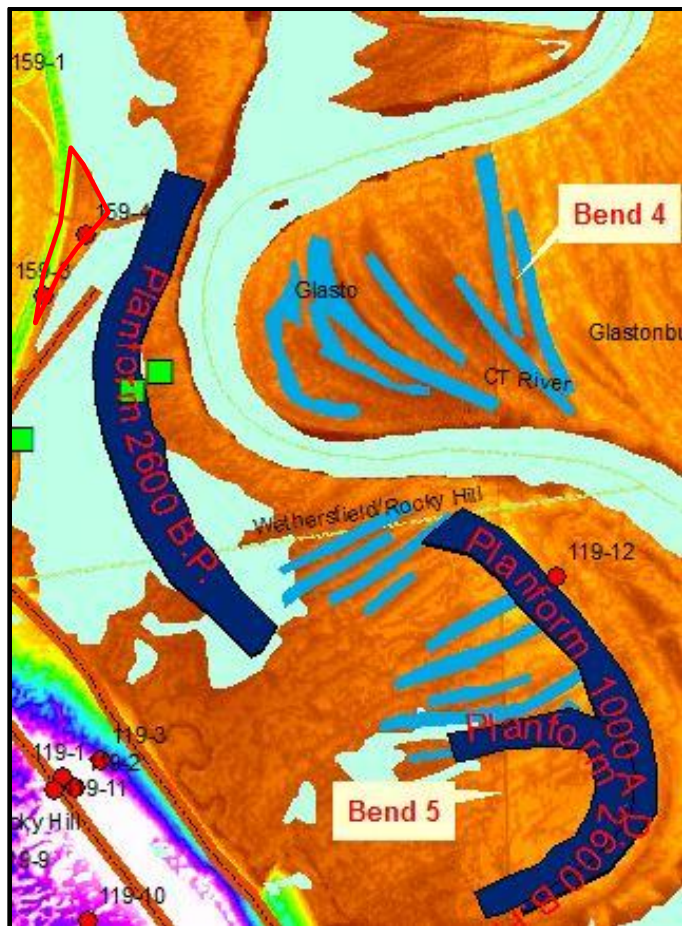


Figure 6.8 Digital Elevation model with reconstructed planform dynamics. The light blue marking represent planform dynamics (3000B.P.-2600B.P). and also indicate erosion areas not capable of preserving archaeological sites established between 3000-2600B.P. Note the elevated triangular area (red) behind the fault line with two archaeological sites , 159-3 and 159-4.

Archaeological Site Distribution and Planform Dynamics: (Bend 5/6)

The planform dynamics reveal that around 2600B.P. meander bends 4 and 5 were located in the eastern most portion of the floodplain (Figure 6.8). Therefore, no Archaic Period sites could have been preserved in the northern and central portions of meander bend 5 (Figure 6.8). There is limited data demonstrating meander bend 6 migration. One small-Hadley Silt Loam ridge visible on 1934 aerial suggests that meander bend 6 was located slightly northwest of its present day position (in present day Rocky Hill) but has generally been constrained by bedrock and terrace deposits (6.4 and 6.6). There is

one site, 119-5, located on this small ridge. It was reported as a surface scatter with Late Archaic diagnostics. It is unclear if the site was established after meander migration or if the adjacent bedrock merely allowed for preservation of artifacts.

The planform dynamics indicate that there is a potential for Woodland Period sites. After 2600 B.P. meander cut off is likely to have occurred, therefore, any sites created between 3000-2600B.P. would have been subject to massive flooding and may likely be preserved. The Morgan Site (119-12) is the largest, intact, and most documented site in the study area. It was established well after the enlargement and migration of meander bend 5. The site is located on and limited to a long narrow ridge, several acres long and 600m away from the present river course (Cooke (1988:4; Lavin 1988) (Figures 6.8 and 6.9). There is evidence of multiple occupations spanning two centuries of the Late Woodland Period on this single ridge (A.D. 1170, A.D. 1320, and A.D. 1360) (Lavin 1988). The high spatial congruity along the ridge indicates that Late Woodland populations had a preference for the same place. The 1979 archaeological survey of the Glastonbury floodplain also revealed the same correlation of large sites with multiple components located on long narrow ridges (McBride and Dewar 1993).

The presence of Late Archaic through Late Woodland sites (54-50, 54-47, 54-90, 54-138, 54-124, 54-101, 54-80, 54-48, 54-87, 54-51, 54-53, 54-52, 54-136, 54-79, 54-55, 54-54, 54-56, 54-57, 54-58) on floodplain ridges in meander bends 6 is indicative of a settlement preference for these locations. Although limited data exists for the shape and position of meander bend 6 it is clear that it is relatively constrained by bedrock and terrace (Figure 6.9). Any erosion of the floodplain within meander bend 6 would be limited to the north and west, as a result of this meander's enlargement into Glastonbury (Figure 6.9).

All of the known archaeological sites within this meander bend are multi-component (Late Archaic -Late Woodland periods) with Terminal Archaic and Early Woodland Period components less numerous than the other periods. The Late Archaic Tinkham Phase sites on the floodplain (119-5, 159-4, 54-32, 54-50, 54-47, 54-138, 54-48, 54-49, 54-80, 54-87, 54-52, 54-53, 54-56) have all been classified as village sites (Dewar and McBride 1992). These floodplain sites are less than 10m wide and hundreds of meters long and always limited to the ridges or “knolls” (Dewar and McBride 1992). Overlapping archaeological features as well as botanical and faunal data indicated that the sites consistently served as residential base camps for multiple occupation sequences. In contrast, there are only 3 Terminal Archaic components (54-48, 54-52, 54-53) on the floodplain. All three Terminal Archaic floodplain components also had Late Archaic components. None of these Terminal Archaic floodplain components are larger than 300 m² (Dewar and McBride 1992). Due to the decrease in site size and number of sites on the floodplain during this later period as well as the relatively high number of Salmon Cove Phase sites on the terraces (54-3, 54-21, 54-23, 54-24, 54-25) (Dewar and McBride 1992) hypothesized a settlement shift. Dewar and McBride (1992) argue that a shift from large floodplain occupations to terrace occupations could have allowed for an earlier spring occupation of the alluvial environment. The close proximity of the terrace to the river as well as the height above floods may have allowed for spring/summer use of the river despite heavy spring flooding (Dewar and McBride 1992; Thorson and Tryon 2003).

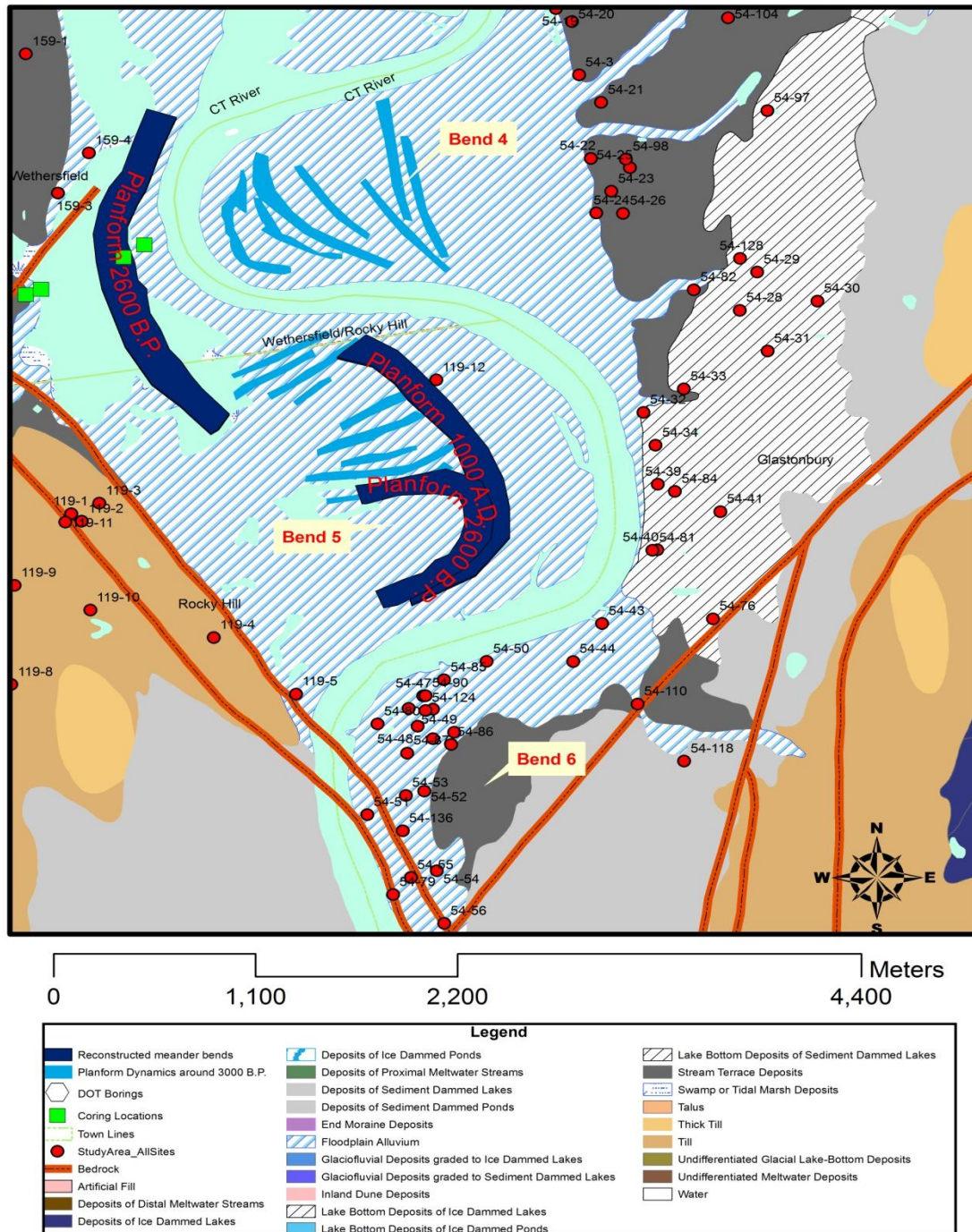


Figure 6.9 Archaeological sites in bends 5 and 6. Note the possible location of meander bend 6 around 2600B.P.

Dewar and McBride (1992) argue that a shift from large floodplain occupations to terrace occupations could have allowed for an earlier spring occupation of the

However, since the Terminal Archaic Salmon Cove Phase terrace sites are very small and there is scant evidence of Terminal Archaic occupation of the valley's uplands (54-41, 19-1, 119-2, 119-3) (Figure 6.10). It is more likely that precontact meander migration has fragmented the Terminal Archaic archaeological site distribution on the floodplain.

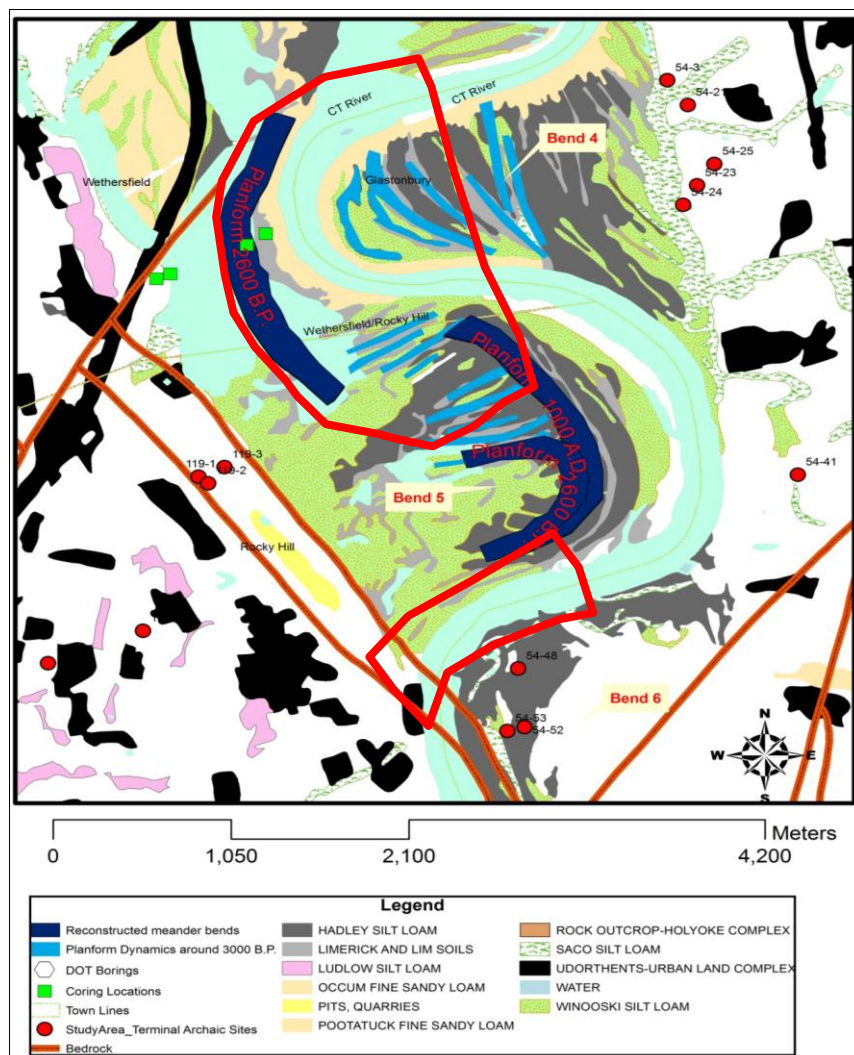


Figure 6.10 All Terminal Archaic sites in the study area. The areas highlighted in red indicate areas that could have been inhabited during the terminal Archaic Period but would have been eroded by precontact planform dynamics.

Given the reconstructed precontact planform dynamics and the Archaic/Woodland Period preference to locate sites on ridges it is possible that the Terminal Archaic residential base camps were located along the 2600 B.P. constricted river (meander bends 4/5/6) (Figure 6.10).

When the meanders began to enlarge, and migrate east the sites located closest to the

constricted river course were eroded (Figure 6.10).

The floodplain of meander bend 6 is also unusual because of the presence of Early Woodland (2700 B.P.) components (54-138, 54-48, 54-43, 54-56) (Figure 6.11) which are scarce anywhere else in Connecticut. In the study area there are no Early Woodland sites west of the river. The Early Woodland Broeder Point Phase floodplain

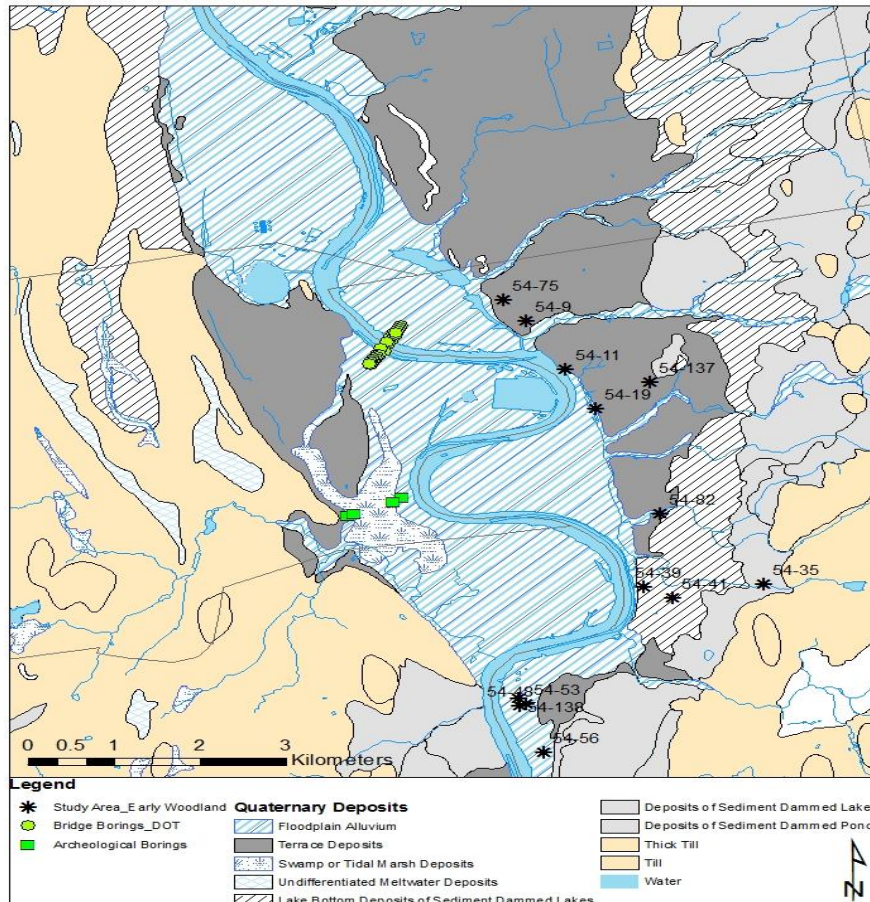


Figure 6.11 All Early Woodland sites in the study area.

site distribution in meander bend 6 is similar to the earlier Terminal Archaic Salmon Cove Phase site distribution, in that the floodplain sites are small. However, on the terraces it is more similar to the Late Archaic Tinkham Phase site distribution. Of the

nine Early Woodland

components on the Glastonbury Meander terraces and valley uplands, five coincide with Tinkham Phase components (54-75, 54-9, 54-11, 54-39, 54-41). Given this distribution it is conceivable that planform dynamics from 3600 B.P. to A.D. 1000 fragmented the Early Woodland archaeological site distribution. However, given the lack of Early

Woodland sites in the uplands west of the river it is also very possible that the paucity of Early Woodland sites reflects a real socio-cultural issue.

In McBride's study of the Lower Connecticut River valley (1984) he documented another potential settlement pattern shift during the Middle Woodland's Roaring Brook Phase (2000-1200BP). This shift entailed a return of residential occupations restricted to the Connecticut River floodplain and some task specific camps in the uplands. In the study area, there is a remarkable lack of terrace sites and only three sites in the valley uplands (54-5, 54-39, 54-41). The Roaring Brook Phase floodplain sites differ from Tinkham Phase site distribution in that the floodplain sites are larger and seem to reflect much longer periods of use (McBride and Dewar 1987). In the study area almost all of the Middle Woodland floodplain sites (54-138, 54-48, 54-56, 54-58, 54-44) are also located on ridges (Figure 6.12). These sites are also multi-component found with Late Archaic sites (Figure 6.12). Site 54-44 is the only Middle Woodland component on the floodplain not located on a ridge. It is also the only Middle Woodland component that was not found with any other component and is the most northerly of all the Middle Woodland components. The lack of single component Middle Woodland components west of the present day river and paucity of single component Middle Woodland components east of the river supports the hypothesis that most Middle Woodland floodplain residential base camps were destroyed by Pre-contact meander migrations beginning around 2600B.P.

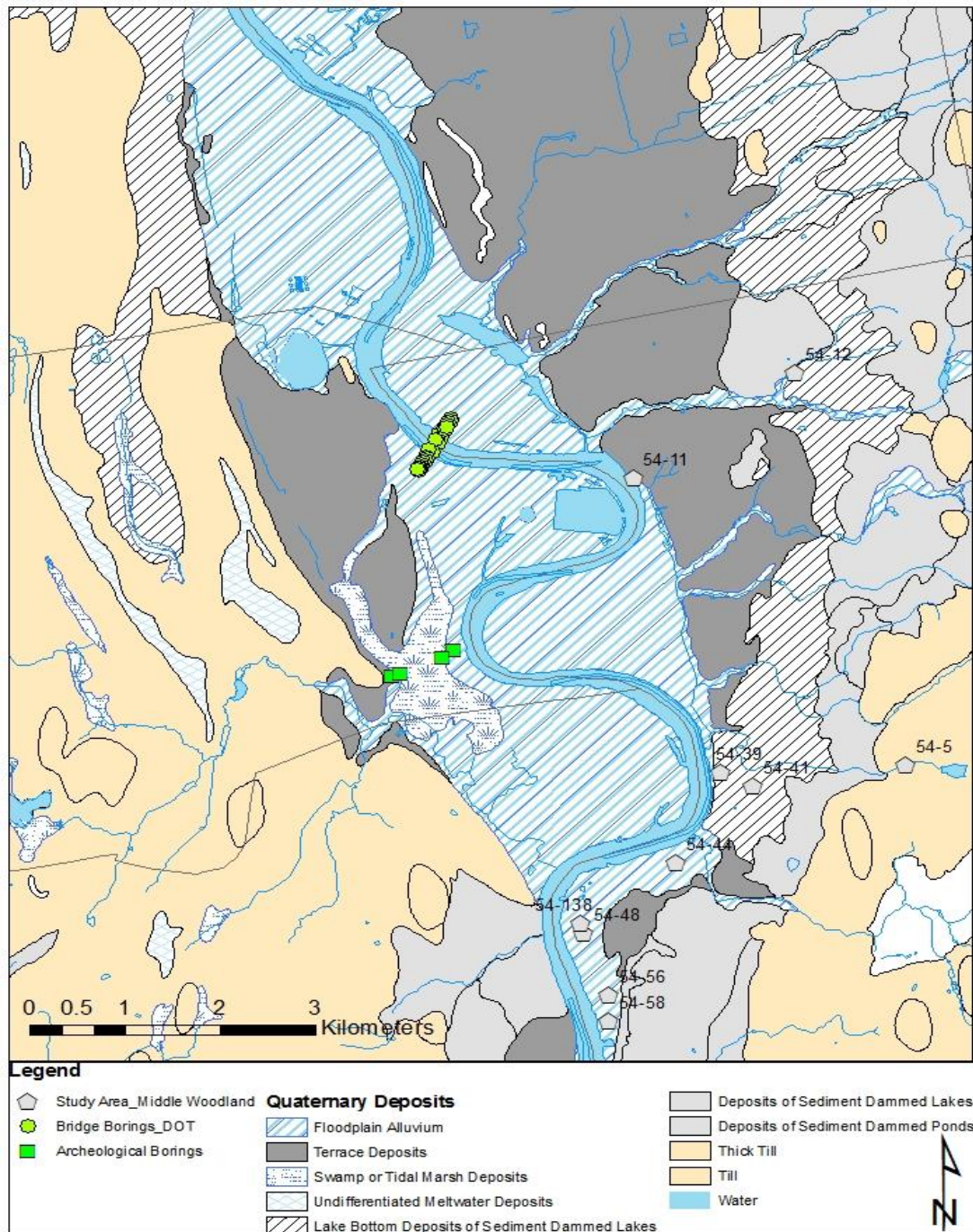


Figure 6.12 All Middle Woodland sites in study area

With the exception of one site, 54-43, all the Late Woodland floodplain sites in meander bend 6 have a Late Archaic component (54-48, 54-56, 54-138) (Figure 6.13). These Late Woodland sites are all small classed as task camp sites and are all located on ridges. The Hollister site (54-39) located on the Glastonbury terrace is the only residential village

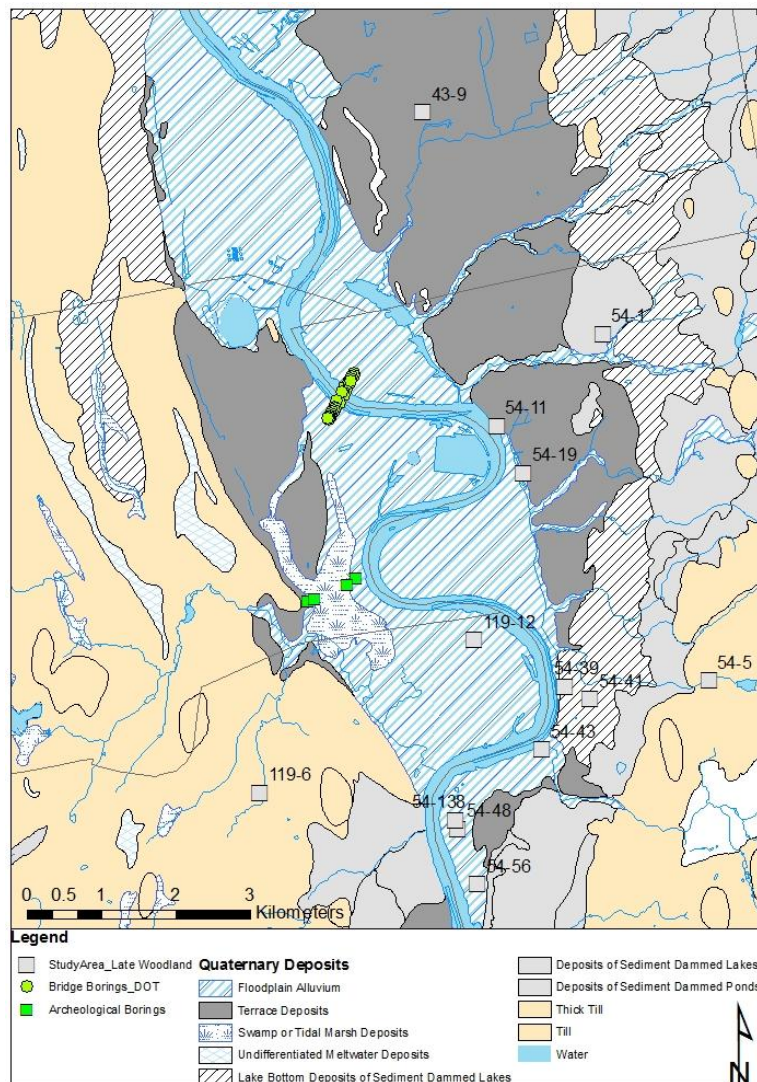


Figure 6.13 All Late Woodland Sites in study area.

site east of the river. Given the size of these sites it is possible they served as the only residential villages and the smaller sites were occupied by household units. Given Pre-contact planform dynamics and the presumed preference to locate sites on floodplain ridges there is no other preserved area suitable for these large settlements.

6.5 Summary and Conclusions

This chapter demonstrates how the planform dynamics affected Pre-contact settlement and then

distorted these archaeological settlement patterns. The planform dynamics of the Glastonbury Meanders distorted much of the Late Archaic through Middle Woodland archaeological site distribution in the reach, particularly within meander bend 4, 5, and 6. The reconstructed planform dynamics show that sites established destroyed sites established on these floodplains prior to 3000B.P. and up to 1000 B.P. had almost no chance of preservation. This proposed meander constriction (2600 B.P) and enlargement (2000B.P) meander migration scenario distorted the pattern so that it

appears that: 1) Archaic Period settlements only occurred west of the river; 2) Terminal Archaic populations shifted to terrace occupations; 3) Early and Middle Woodland components only exist as small components of what are mostly characterized as Late Archaic base camps.

In reconstructing the planform dynamics it was revealed that the constraints on meander bend 6 mean that this floodplain area was likely eroded on its northern and western edges after 2600 B.P. Therefore, the site distribution, particularly in relation to the floodplain landforms is representative actual settlement system preferences. This area has a number of archaeological sites with the majority of them located on floodplain ridges. It appears that this settlement preference for these ridges began in the Late Archaic Period. The next chapter will investigate the possible benefits this floodplain landform may have offered Pre-contact populations.

Chapter 7

Alluvial Floodplain Landforms and Human Settlement

7.1 Introduction

The Glastonbury Reach alluvial floodplain is comprised of numerous landforms created by the meandering river and sustained by tributaries and annual spring floods. Point bars, levees, scroll-bars and sloughs (ridge and swale topography), cutoffs (oxbow lakes, paleochannels), and backswamps (marshes, tidal flats) are some of the floodplain elements presently in the Glastonbury Reach. All of these landforms are products of a meandering regime and could have existed in the past, although their sizes and configuration would have changed as the planform changed. Nevertheless, each of these alluvial floodplain landforms offers a unique environment that can be exploited by human groups. This chapter briefly examines the conditions under which the ridge and swale landforms emerge, and the biotic elements associated with these landforms.

The high spatial congruity along ridges indicates that Late Archaic Period through Late Woodland populations had a preference for this same floodplain ridge locale. The 1979 archaeological survey of the Glastonbury floodplain revealed the correlation of large Archaic Period sites with multiple components located on long narrow ridges (McBride and Dewar 1993). Moreover, in Feder's (2001) Farmington Valley Watershed study he also noted that Native American groups sometimes located themselves *along* landforms "too small to be discerned on standard USGS, 7.5 minute, 1:24,000 topographic maps (Feder 2001:19)". Most archaeological reports have identified these elevated long linear landforms as "knolls."

7.2 Floodplain Landform Development

The existence, development, and arrangement of floodplain elements provide a record of channel activity. It is somewhat necessary to understand how these landforms emerged in order to infer and constraints or opportunities they might have offered past societies (Brown 1997). The landforms examined herein are those that could only have formed around 6.4 -4.2 ka., as a result of the emergence of meandering regime and stable floodplain (Thorson et al. 2014; Patton and Horne 1992). It is hypothesized that scroll bars are correlated with Pre-contact sites because of the settlement and subsistence opportunities they offered to Late Archaic through Late Woodland groups.

Scroll bars are the ridge and swale topography that appear curved in planform.

They are composed

of sand and silt.

There are two

different

hypotheses

regarding their

formation. The

first hypothesis is

that they are the

result of the

spatio-temporal variations in point bar¹¹ height as the point bar accretes laterally to

form the floodplain. The alternative hypothesis is that the topography is the result of

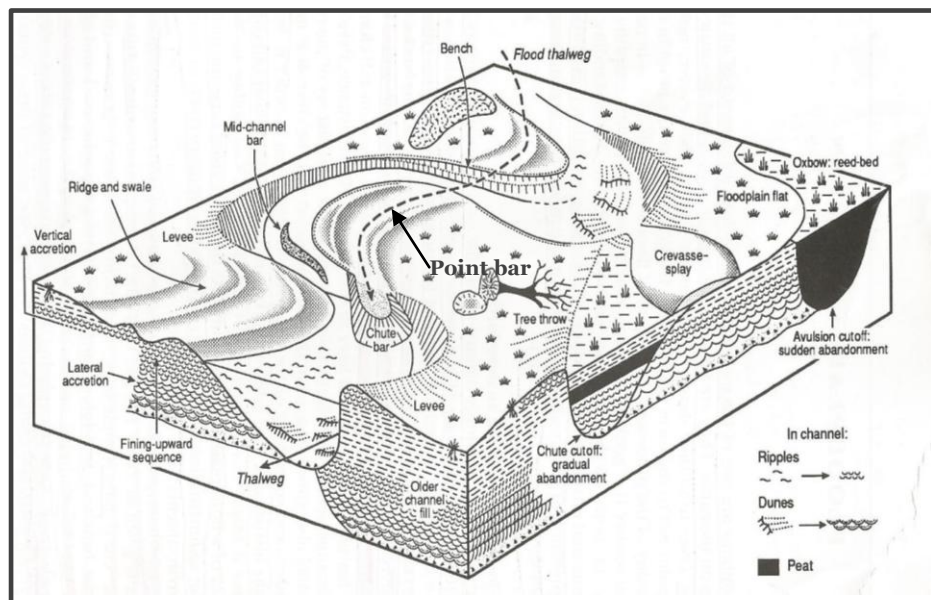


Figure 7.1 Diagram of landforms associated with a meandering river and its floodplain. Adapted from Brown (1997).

¹¹ Point bars grow out from the bank into the channel. They are caused by the deposition of gravel, sand, and silt on the inner side of meanders (Figure 7.1)

alternating long stable periods (no channel migration) during which natural levees¹² form and brief unstable periods (channel migration) during which levees do not have time to form. In this scenario the ridges and swale topography are old levees and non-levees formed by a laterally migrating channel (Brown 1997). Although the formation of ridge and swale topography is relevant for understanding the archaeological site distribution this chapter focuses on the stability, biotic productivity and exploitability of these landforms, not their origins.

7.3 Landform Stability and Biotic Productivity

The Glastonbury floodplain during the precontact period was vegetated (Cronon 1988; McBride and Dewar 1993; Webb et al. 1993; Thorson et al. 2014). This vegetation persisted even during times of instability (6.4-2.7 ka) or increased flood volatility (2-1ka) (Thorson et. al 2014). Ethnohistoric records, archaeological and geomorphological evidence indicate that the alluvial river valley and the floodplain itself consisted of a patchwork forest or an open park-like forest interspersed with meadows. The ethnohistoric record indicates that Native Americans intentionally created this park-like forest and meadow landscape in order to reduce forest underbrush, improve the quality of forage for animals, clear fields for planting, encourage the growth of useful plants, such as berries and herbs and improve the soil quality (Cronon 1983). One of the first English settlers, William Wood noted the following:

“it is the customs of the Indians to burne the wood in November when the grasses withered, and leaves are dried. It consumes all the underwood, and rubbish, which otherwise would overgrow the county, making it unpassable, and spoil their much affected hunting.”

¹² Levees are linear mounds of sand running adjacent to the edge of the channel. They are formed by the deposition of sand at the point at which the flood waters spill out from the channel across the floodplain. (Figure 7.1).

Also growing in meadows and around the meadows were annual grasses such as willow (*Salix*), broomstraw (*Andropogon*), and American lotus (*Nelumbo lutea*)(McWeeney 1999;Smith 1987; McBride 1978). Hunter-gatherers relied on these native trees, nuts, fruits, berries, and tubers, and plants, as well as acorn (*Quercus alba*), black walnut (*Juglans nigra*), hickory nut (*Carya*) blueberries(*Vaccinium*), strawberries(*Fragaria*) , and, sunflowers and Jerusalem artichokes(*Helianthus annuus* and *Helianthus tuberosus*), sumpweed (*Iva annua*), lambsquarters, pitseed goosefoot (*Chenopodium berlandieri*) (Cronon 1983; Smith 1987 Bendremer et. al 1991). Smith (1987) demonstrates that Native Americans as early as 3500 B.P. were domesticating sunflower, sumpweed, and chenopodium. Sumpweed and chenopodium, in particular, frequently colonize recently disturbed floodplain soils (Smith 1987). Given this larger cultivated park-like landscape the floodplain's ridge and swale topography provided unique opportunities for hunter-gatherers/emerging horticulturalists.

It has also been hypothesized that frequent and heavy spring flooding made Pre-contact floodplain occupation difficult therefore, terrace locations were preferred locales (McBride and Dewar 1993; Thorson and Tryon 2003; Thorson et al. 2014). An alternative hypothesis is that the spring floods events prior to colonization actually enhanced the landscape for Native Americans.

The evidence indicates that frequency and magnitude of all flood events has only increased as a result of European agricultural/grazing practices, timbering and urbanization^{13 14}(Cronon 1983). Furthermore, a stable meandering stream that floods

¹³ Grazing resulted in loss of native vegetation and led to compaction which caused erosion. The removal of vegetation through grazing and land clearing also led to an increase in surface temperature (hotter springs/summers and shorter winters) this resulted in an earlier snow melt which would have increased the intensity and frequency of spring floods. In addition the lack of vegetation and transpiration meant more surface runoff which heightened steam waters (Cronon 1983).

seasonally may not have been a hindrance to hunter-gatherer society that used mobility as a means of managing their environment. Thorson et al. (2014) demonstrates that the seasonal nature of the majority of floods and the flood mechanism, hydraulic ponding, draped the floodplain and ridges with a thin layer of silt that did not destroy vegetation, even during times of higher volatility (6.4 -2.7 ka; 2.0-1.0 ka). This thin layer of fertile alluvial silt that settled on the surface of ridges may have actually made the land more fertile. While the water that filled the swales (depressions adjacent the ridges) often forms a swamp-like environment that could have been used to grow water loving plants, such as lotus, or irrigate plants growing on the adjacent rows. Mollisson (1988) noted that the areas around where these swales existed were actually more productive, supported much larger trees, a thicker humus, and much more bio-diversity because the swales provided passive irrigation.

Rignall (1977) noted this ridge and swale topography at the Long Knoll site, in the Glastonbury study area, and suggested that new ridge and swale deposition may have been exploited by new groups. The ridge and swales topography could have offered the following opportunities to hunter-gatherers and groups engaging in plant-husbandry:

- slightly elevated above the rest of the floodplain
- fresher, more fertile soils
- slightly better draining land than the rest of the floodplain
- adjacent swales offered a means to store water
 - irrigate plants
 - animal habitat (hunting)
- recognizable feature on the landscape that could be easily returned to

In New England all discoveries of more than one cultigen have been made at inland riverine sites (Ceci 1982; Bendremer et al. 1991). The earliest evidence of weedy cultigens is at Woodchuck Knoll (132-44), a Late Archaic (3690 B.P.) and Terminal

¹⁴ Presently, the Glastonbury Reach the flood stage height is 16 ft (4.8 m). Floods on record indicate that this height has been surpassed 180 times since the 1840's (Kinnison 1938; Ahearn 2005).

Archaic Period (3200 B.P.) floodplain ridge site (4-5 m above floodplain), located on the Connecticut River, approximately 15 km north of the study area (McBride 1978). The floral remains identified revealed that the inhabitants of Woodchuck Knoll were exploiting a biologically diverse environment (McBride 1978). American lotus, which grows in still waters, indicates the use of backswamps or swales, chenopodium, walnut, and hickory could have been grown directly on the well drained floodplain ridges. Long Knoll is also located on a ridge and has evidence of several occupations¹⁵. This site is several acres long and approximately 500 m away from the present day river course. In addition to artifacts, such as mortars, pestles, and pitted stones, indicative of seed and nut processing, this site contained features with ethnobotanical remains such as goosefoot, blueberry onion, huckleberry, walnut, butternut and dogwood (Rignall 1977).

The Late Woodland Period, Morgan Site (119-12), also located in the study area on a long narrow ridge, several acres long and 600 m away from the present river course (Cooke (1988:4; Lavin 1988) also had similarly diverse floral remains. Chestnut, hickory, mulberries (*Morus*), chenopodium, and knotweed (*polygonum*) as well as corn (*Zea Mays*) (Lavin 1988). There is evidence of multiple occupations spanning two centuries of the Late Woodland Period on this single ridge (A.D. 1170, A.D. 1320, and A.D. 1360) (Lavin 1988). The Late Archaic sites on ridges are evidence of a system of plant-husbandry involving trees, shrubs, perennial plants, and self-sowing annuals was a precursor to the adoption of maize based horticulture by the Late Woodland Period (A.D 1000-1500). Moreover, plants, such as chenopodium, and tubers, such as American lotus, would be available for consumption in the early spring months March,

¹⁵ In 2014 the Connecticut Office of State Archaeology partially excavated the Long Knoll ridge and identified and dated (4230 ± 30rcBP) what is likely a possible house floor (Brian Jones, Personal Communication).

April and May (maize sowing months), which also coincides with the anadromous fish runs that were exploited by populations occupying large river valleys (Speiss 1983; Carlson 1988; McBride and Dewer 1992).

7.4 Evidence for Landform Hypothesis: Reach 11 and Windsor Reach

To further explore this ridge and swale landform preference hypothesis, other archaeological sites (outside the study area) identified as being on a “knoll” were sought. The Connecticut site file database revealed that of the 3423 precontact sites, listed in 2007, 206 had been identified, by the site recorder, as sites located on “knolls”. However, it became apparent that “knoll” sites are located in all Connecticut environments, such as in wetlands and small streams, and not just the major alluvial valleys. cursory examination of these other “knoll” environments in GIS, revealed that the term “knoll” was at times used to describe any raised surface on the landscape. Since this dissertation contends that “knolls” in alluvial meandering environments are in fact point bars or levees created as the river migrated across its floodplain, the unit of study is isolated to the alluvial reach. The geological history, planform, landforms contour elevations, soils, landforms, and archaeological site distribution must be studied together. Examples of two alluvial reaches in Connecticut that have undergone some level of archaeological survey are the Housatonic River north of Falls Village, and the Windsor Reach of the Connecticut River. However, the geological information is not as rich as that of the Glastonbury Reach.

The segment of the Housatonic River, north of Falls Village in northwestern Connecticut, is a meandering alluvial reach (Figure 7.2) identified as Reach 11 (EPA 2008). This reach is approximately 5 km in length with a floodplain 15–1000 m wide. The floodplain is presently dotted with farmland and former oxbows that are now

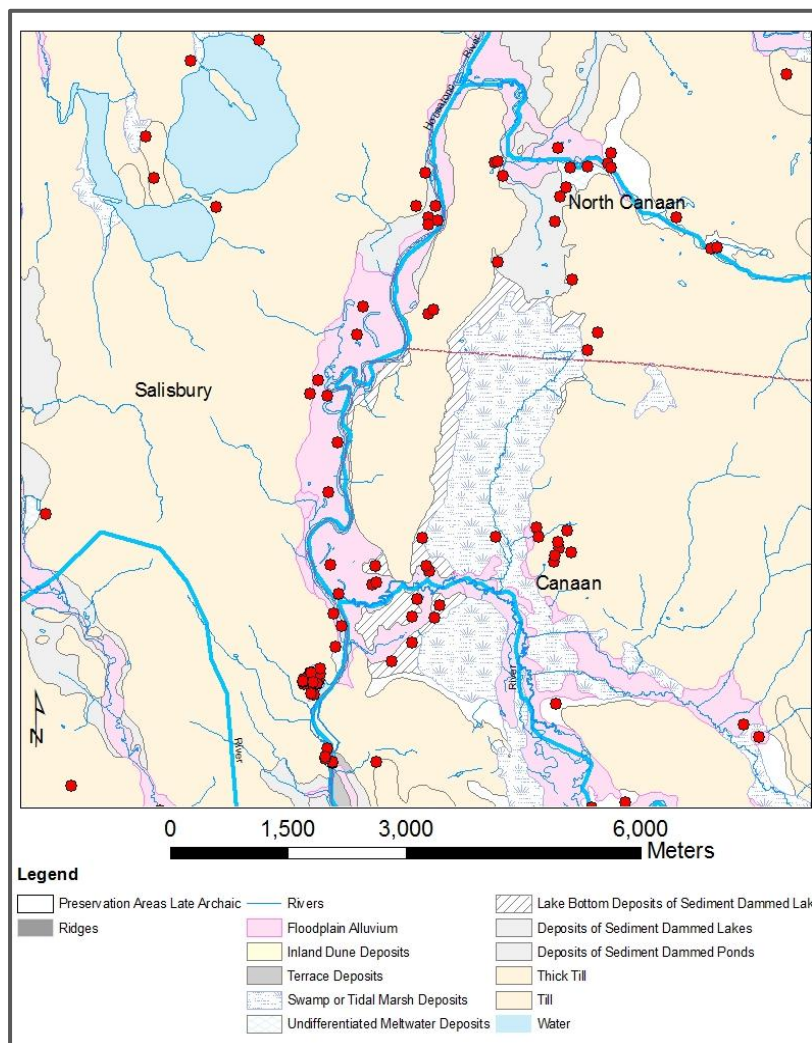


Figure 7.2 Archaeological site distribution of Reach 11, Housatonic River

vegetated wetland. This multi-habitat rich area may have resulted in settlement and subsistence adaptations substantially different from that of central and coastal Connecticut. It is possible that the resource-rich environments may have encouraged mobility rather than intensification of any one habitat. Wadleigh (1981) and Feder (1981, 1990) hypothesized that by the Late Archaic and Woodland

Periods, the Highlands

supported year-round subsistence-settlement systems. Reach 11 contains nine Pre-contact archaeological sites (21-4, 21-3, 21-7, 122-17, 122-16, 122-13, 122-14, 122-15, 122-12). A cursory examination of the archaeological site distribution of the valley reveals that Late Archaic sites are more numerous than sites from any other period. However, on the floodplains of Reach 11 Woodland Period sites are more prevalent than any other period. There are a total of 17 archaeological sites in this segment of the floodplain. Five (122-16, 122-13, 122-12, 21-3, 21-4) of the six Late Woodland floodplain sites are on floodplain ridges (knolls). Two of these ridges appear to be in areas presently classified

as riverine wetlands. This current landform classification is indicative of lower lying swale areas typical of meandering streams.

The archaeological site distribution could be a matter of fragmentation due to meandering or the presence of only Late Woodland on these ridges may indicate that landscape element selection in northwestern Connecticut did not occur until this time

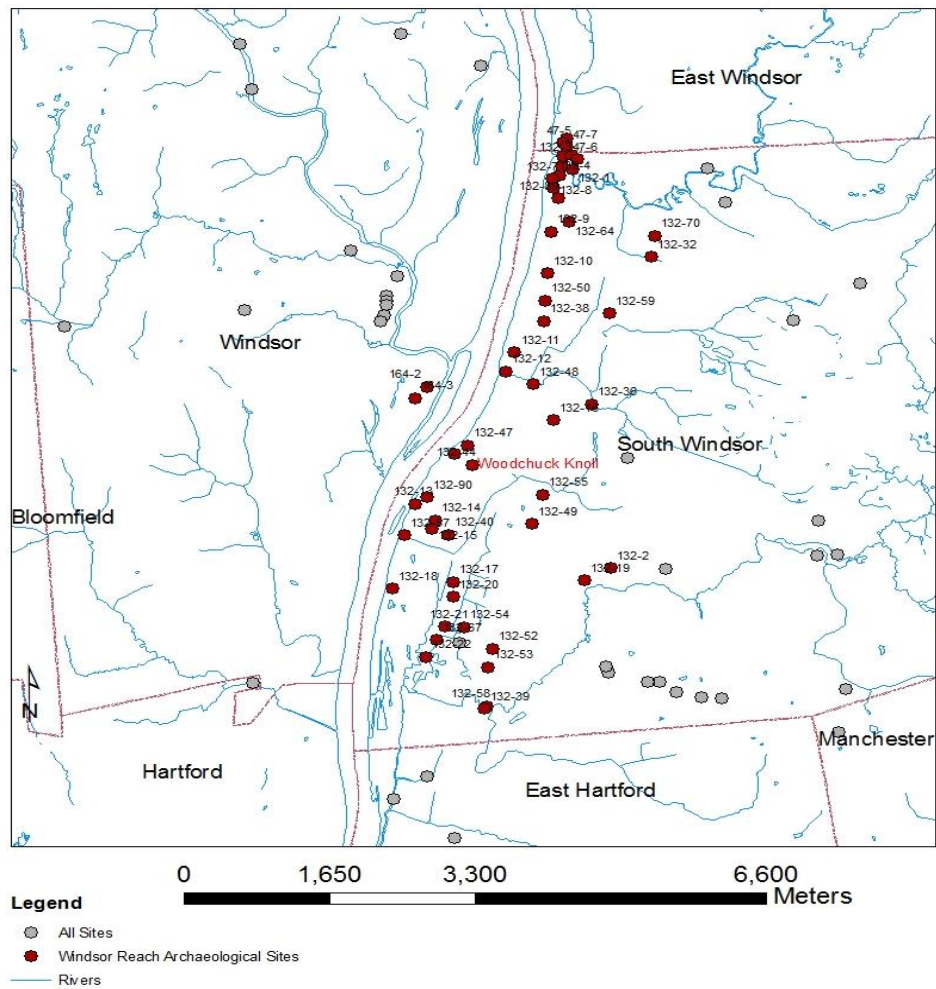


Figure 7.3 Archaeological Site distribution in Windsor Reach, Connecticut River

period. The paucity of Late Woodland sites outside the floodplain environment indicates a settlement shift focused on the floodplain resources did occur in the uplands.

The Windsor Reach
The Windsor Reach of the Connecticut River is approximately 10

km in length with a 1-2 km wide floodplain (Thorson et al. 2014). This section of the Connecticut River contains 39 archaeological sites on its floodplain and 12 on its terraces (Figure 7.3). Of the 39 floodplain sites in the Windsor Reach, 9 floodplain sites

in the Windsor Reach of the Connecticut River, nine have Late Archaic components; three have Terminal Archaic components; three have an Early Woodland component; six have a Middle Woodland component; and 14 have a Late Woodland component. In addition, there are several Native American burials, of unknown time periods, on the floodplain ridges and small camp sites (<500 square meters) scattered on the floodplain. Presently, there are ten sites that were identified by the recorder as being a “knoll” excavation. Two of these ten sites include: Woodchuck Knoll (132-44) and the Sperry Road site (132-62). Both of these sites have Late and Terminal Archaic components. Woodchuck Knoll is the site with the earliest recorded use of cultigens dated. The other eight “knoll” sites (132-1, 132-18, 132-55, 132-64, 132-65, 132-70, 164-2, 164-3) have only Woodland Period components (McBride 1978; Pagoloutas 1990). However, examination of the archaeological site distribution overlaid with hillshade imagery revealed many more sites located on raised surfaces than what was identified in state site files. For example, 132-9 a camp site with Late Archaic, Terminal Archaic, Early Woodland, Middle Woodland, and Late Woodland components is on a 3 m rise above the floodplain, as are sites 132-50 (Early Woodland), 132-38 (Late Woodland) and 132-89 132-57, 132-18, 132-62, 132-8, 132-4 (Figure 7.4). This qualitative research demonstrates a need for more detailed landform studies of meandering alluvial systems.

7.5 Summary and Conclusion

The presence of Late Archaic through Late Woodland Period sites on long linear ridges running parallel to the present day river has previously been thought to be a consequence of differential preservation. Additionally, the frequency and magnitude of flood events over the past 150 years has contributed to the belief that the floodplain was too volatile a place to inhabit. However, it is possible that the river’s activities for the

past 150 years have been more volatile than they ever were prior to the introduction of European agri-pastoral practices, deforestation, and urbanization. These introduced practices resulted in increased surface runoff and erosion and in an increase in stream power. In the Pre-contact period, flooding may have been limited to annual spring floods and major but not frequent events such as hurricanes¹⁶. Floodplain ridge and swale topography may have offered inhabitants a place to better exploit a more- diverse range of plant resources. The ridges would have been slightly elevated, easily recognizable, better draining and more fertile capable of supporting a range of trees, shrubs, perennial plants, and self-sowing annuals. A brief examination of Reach 11 of the Housatonic River and the Windsor Reach also indicates that the development of alluvial meandering landforms is correlated with a shift in settlement practices in other reaches. Further study of the development and timing of alluvial processes and landforms as well the archaeological sites and archaeological site distribution in large alluvial meandering systems is necessary to engage in more meaningful settlement pattern analysis.

¹⁶ The 1692 flood which. Kinnison (1938) estimates that the flood stage height reached 26' occurred in August. This flood was reported to have fallen on the same day that Virginia colonists reported a hurricane.

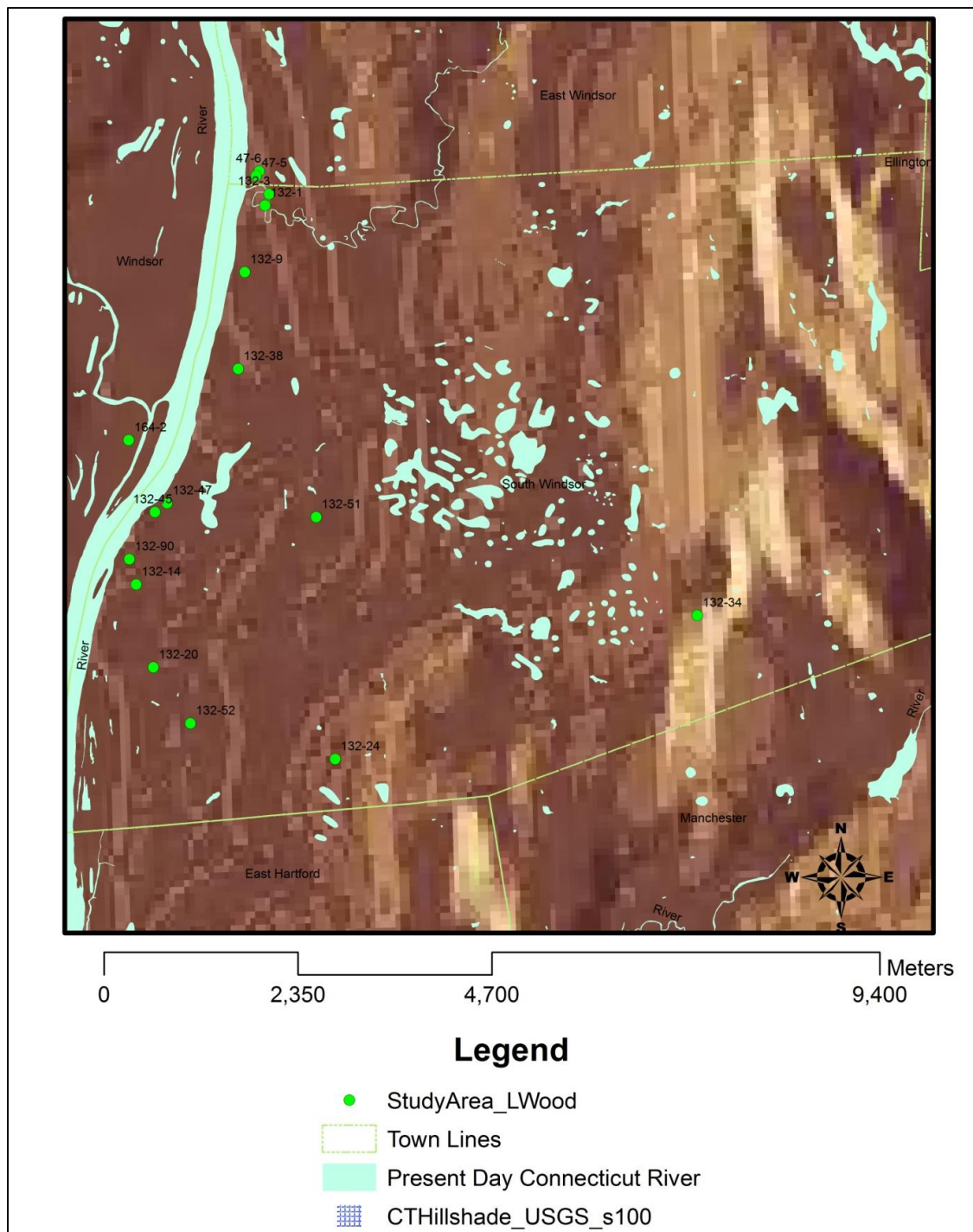


Figure 7.4 Hillshade imagery Windsor Reach of Connecticut River

Chapter 8

Conclusions

The Glastonbury Reach has had a meandering regime since 6.4 – 4.2 ka (Thorson et. al 2014; Patton and Horne 1992). At this time, the river began to meander across the floodplain creating many of the floodplain landforms that exist, only in parts, today. Late Archaic through Late Woodland sites were established on the floodplain of the Glastonbury Reach during these periods of active meandering. The ridge and swale floodplain landforms, created by the meandering river, appear to have been intentionally sought after by the inhabitants of the river valley. Although some of the archaeological record has been destroyed by the meandering channel this dissertation demonstrates that by integrating geomorphology, taphonomy, formation processes, and ethnoarchaeology with the landscape perspective, the relationship between one set of defined variables had on the archaeological record can be discerned.

This research focused on reconstructing the shape and planform of only a segment of the river valley. By adopting this medium-scaled approach to research, patterns in the archaeological site distribution as well planform changes over time could be delineated and the relationship between site and landform could be examined diachronically. The historic planform analysis, which examined planform changes from 1640–1934, revealed that this segment of the Connecticut River appears to be in equilibrium taking approximately 100–150 years to mitigate drastic changes in slope, discharge or sediment load. During periods of equilibrium the river migrates in only a small belt of the valley. This lack of mobility therefore results in large portions of the floodplain remaining untouched (by lateral erosion) for hundreds, perhaps thousands of years. In addition, the geomorphic constraints are such that the middle of the reach

(meander bends 3 and 4) is relatively unconstrained but the top and bottom of the reach (meander bends 1, 2, 5, and 6) are relatively constrained in their migrations. Given the average rate (3.5m/yr) of meander migration the planform changes can be divided into phases dominated by a certain direction in meander migration.

Given the historically established rates and patterns of meander migrations, as well as the radiocarbon dated stratigraphic sections from cores, and the existing geological data it was possible to determine that the dominant direction of migration around 3000B.P. was westward, with meander bend 4 migrating from east to west until it was constrained by exposed bedrock in Wethersfield and Rocky Hill. This migration would have resulted in the creation of a large floodplain area (meander bends 3 and 4 combined) that would have been habitable during the Terminal Archaic, Early Woodland and Middle Woodland Periods (3600-1200B.P.). However, around 2600 B.P. meander bend 5 expanded east and north, which would have resulted in the erosion of most of this large floodplain. These dynamics are reflected in the settlement patterns through:

- A larger number of Late Archaic components on the east bank compared to the west bank.
- A higher number of Late Archaic sites compared to Terminal Archaic components on the east bank
- A higher number of large Late Woodland residential sites compared to Early Woodland and Middle Woodland residential sites on the west and east bank.

Most of the excavated sites on the floodplain of the Glastonbury Reach are located along the long linear ridges of meander bends 5, and 6. These long linear ridges also exist in meander bends 3 and 4 but this analysis shows that all of the ridges in meander bend 3, as well as some of the ridges in meander bend 4 were created in the last 350 years. It does appear that the eastern half of meander bend 4 (Glastonbury) has potential to contain intact Late Archaic deposits.

By integrating the study of the archaeological settlement patterns with the geomorphology of this reach and delineating the planform dynamics this dissertation demonstrates that the paucity of large sites from the Terminal Archaic–Middle Woodland on the floodplain is due to differential preservation rather than cultural preference for terrace locations. More importantly, these reconstructed dynamics reveal that the archaeological site distribution in meander bend 6 is an accurate representation of the Late Archaic through Late Woodland settlement systems. This dissertation provides evidence that indicates the ridge and swale topography was utilized by Pre-contact groups.

It has been argued that most of the known Late Archaic through Late Woodland sites in the Glastonbury Reach are found on the terraces and along the tributaries of the Connecticut River, because these areas provided stable surfaces that would not be threatened by the annual spring floods or the channel migrations (Dewar and McBride 1992, Thorson and Tryon 2003; Thorson et. al 2014). An alternative hypothesis is that the residential villages of these periods were located on the floodplain to utilize the ridge and swale topography that were created by the actively meandering channel, while the terraces were only used for special task camps or temporary camps.

Mollison (1988) has demonstrated that ridge and swale topography, created by meandering rivers, are richer and more bio-diverse than surrounding areas. Moreover, the flooding mechanism, hydraulic ponding/backflooding, incrementally deposited fine layers of silt over the entire floodplain that enhanced floodplain vegetative growth (Thorson et. al 2014). This type of disturbed habitat in floodplain environments has been shown to increase fertility and support the growth of weedy cultivars, such as *chenopodium* (Smith 1987; 1992). Based on archaeological data plant husbandry

systems based on these weedy cultivars began around 3500 B.P. in Southern New England and are believed to be the pre-cursor to maize based horticulture.

The planform analysis indicates that if Terminal Archaic Period sites were located on the floodplain in the Glastonbury Reach they would have been located on the inner bank of the actively migrating channel to best take advantage of the newly created ridges. Therefore, at 2600 B.P. when the river migrated back east these sites were eroded. The Terminal Archaic–Late Woodland Period sites that do exist in Glastonbury's meander bend 6 are all small task camps sites located on ridges that were once previously the site of large Late Archaic sites (Binford 1980; Dewar and McBride 1992)). This change of place function over time is not unusual but, rather it is indicative of cultural or environmental change that has impacted settlement decision making.

Since this archaeological record has been fragmented by the planform dynamics and it is difficult to prove a hypothesis with negative evidence two additional alluvial landscapes were examined to corroborate the correlation between archaeological sites and floodplain ridges. A qualitative examination of Reach 11 of the Housatonic River (Northwestern Connecticut) and the Windsor Reach of the Connecticut River revealed that archaeological sites do fall along long linear ridges. However, in Reach 11 most of these sites are of the Late Woodland Period. In the Windsor Reach many sites were found to be correlated with the ridge floodplain landforms. One of these sites was a Late Archaic and Terminal Archaic Period site, studied extensively and is the oldest site with evidence for the use of weedy cultivars (3250 B.P.) (McBride 1978). However, more detailed examination of the floodplain landforms and the archaeological site distribution, as well as the individual sites on these landforms needs to be done in order

to determine the extent of impact that this floodplain landform on settlement and subsistence patterns.

By incorporating landform studies at the landscape scale the impact of one set of defined variables on another have been identified (Rossignol 1992). The examination of the archaeological site distribution within this detailed context demonstrates that a settlement shift occurred in the Late Archaic Tinkham Phase. The shift entailed use of floodplain ridges created by the meandering river. More fundamentally this dissertation demonstrates the utility of uniting archaeology, geography, geology, and fluvial processes in describing ancient landscapes, and the changing ways in which they were inhabited in prehistory. The methods used in this dissertation provided some new insights into settlement and subsistence patterns. Future research can utilize the same methods to gain a richer appreciation of Pre-contact landscapes and their transformation into the landscapes of the present.

APPENDIX A: Borehole Data: Wethersfield Transect and Putnam Bridge (CTDOT)

Sample CTR1 0'-4'

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
2	-1	0.00	0.00	0.00	100.00
1	0	0.35	1.80	1.79	98.22
0.71	0.5	0.52	2.70	4.44	95.57
0.355	1.5	1.00	5.10	9.55	90.46
0.18	2.5	1.00	5.10	14.66	85.35
0.09	3.5	8.11	41.40	56.08	43.93
0.063	4	4.15	21.20	77.20	22.81
0.037	0.037	4.45	22.70	99.90	0.08

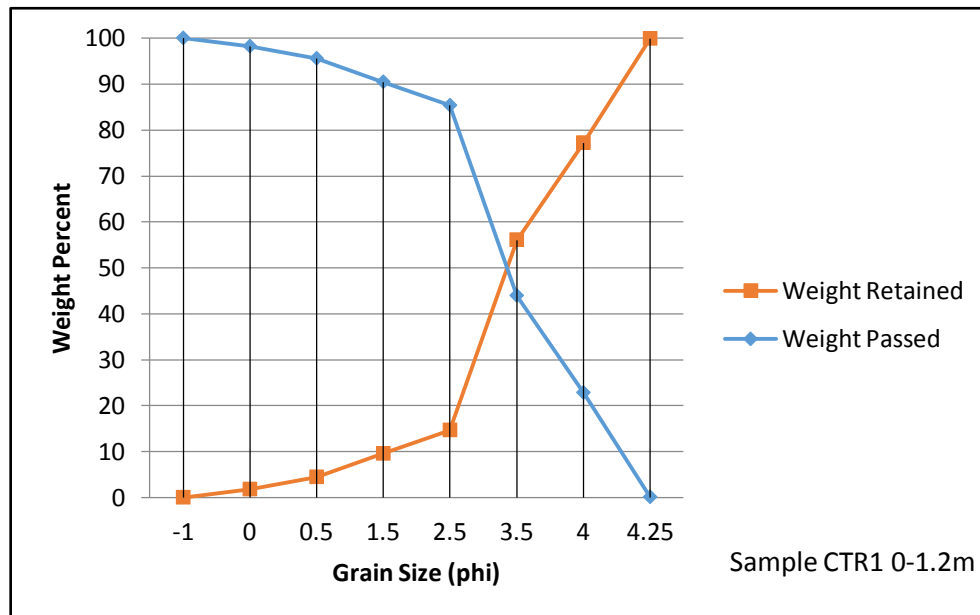


Table A-1 Sample from the first strata (0-4m) of core CTR1: cumulative weight percentages and (b) derived frequency distribution curves.

**CTR1: 5-6m
(16-20ft)**

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
0.706	0.5	0.30	1.58	1.58	98.42
0.353	1.5	0.70	3.70	5.28	94.72
0.248	2	0.50	2.64	7.92	92.08
0.178	2.5	1.50	7.93	15.86	84.14
0.124	3	6.10	32.27	48.10	51.90
0.0635	4	9.80	51.87	100.00	0.00

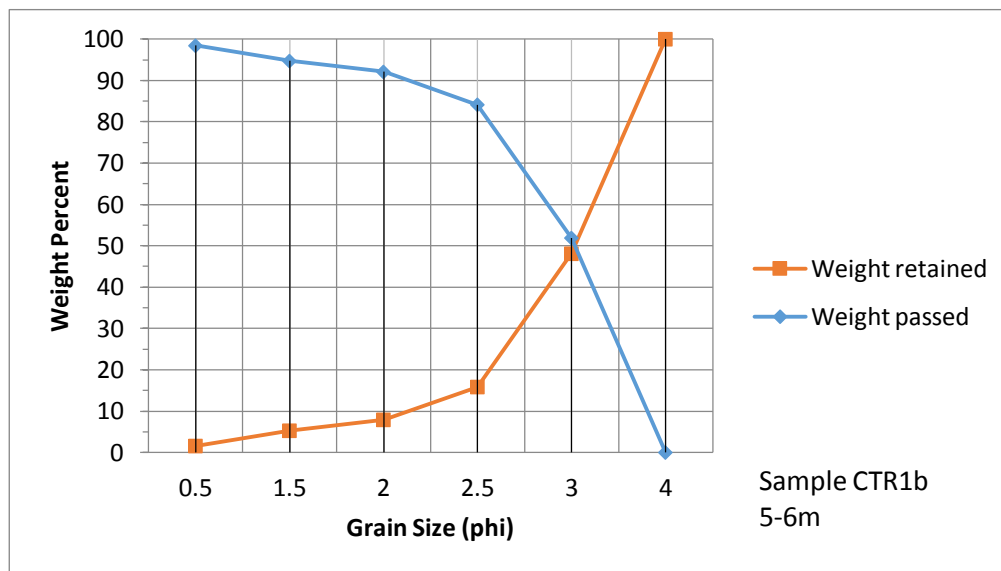


Table A-2 Sample from the first strata (5-6m) of core CTR1: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2a (5.5m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Beaker with sand (grams)	Weight of beaker empty (grams)	Weight of Size Fraction (g)	Weight percent of each fraction	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	32.1	32.1	0	0	0.00	0.00	100.00
0.71	0.5	33.6	33.6	0	0	0.00	0.00	100.00
0.355	1.5	31	30.8	1.2	0.039216	3.90	9.90	90.10
0.18	2.5	33.5	31.2	2.3	0.075163	7.50	13.80	86.20
0.09	3.5	49.45	31.1	18.35	0.599673	60.00	21.30	78.70
0.063	4	36.85	31.1	5.75	0.187908	18.70	81.30	18.70
0.053	4.25	34.4	31.4	3	0.098039	9.80	100.00	0.00

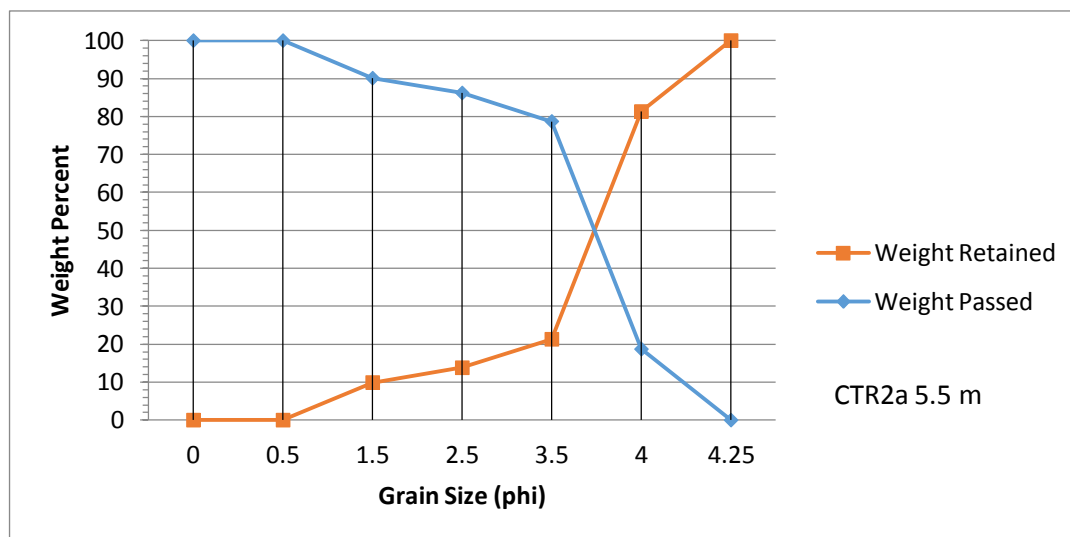


Table A-3 Sample from the first strata (5.5m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2b (5.8m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Beaker with sand (grams)	Weight of beaker empty (grams)	Weight of Size Fraction (g)	Weight percent of each fraction	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	32.1	31.5	0.6	0.019576	2.00	0.94	99.06
0.71	0.5	33.6	31.1	2.5	0.081566	8.20	2.94	97.06
0.355	1.5	46.1	31.15	14.95	0.487765	48.80	11.14	88.86
0.18	2.5	38.6	31.2	7.4	0.241436	24.10	59.94	40.06
0.09	3.5	35.5	31.2	4.3	0.140294	14.00	84.04	15.96
0.063	4	31.4	30.8	0.6	0.019576	1.96	98.04	1.96
0.053	4.25	31.4	31.1	0.3	0.009788	0.98	100.00	0.00

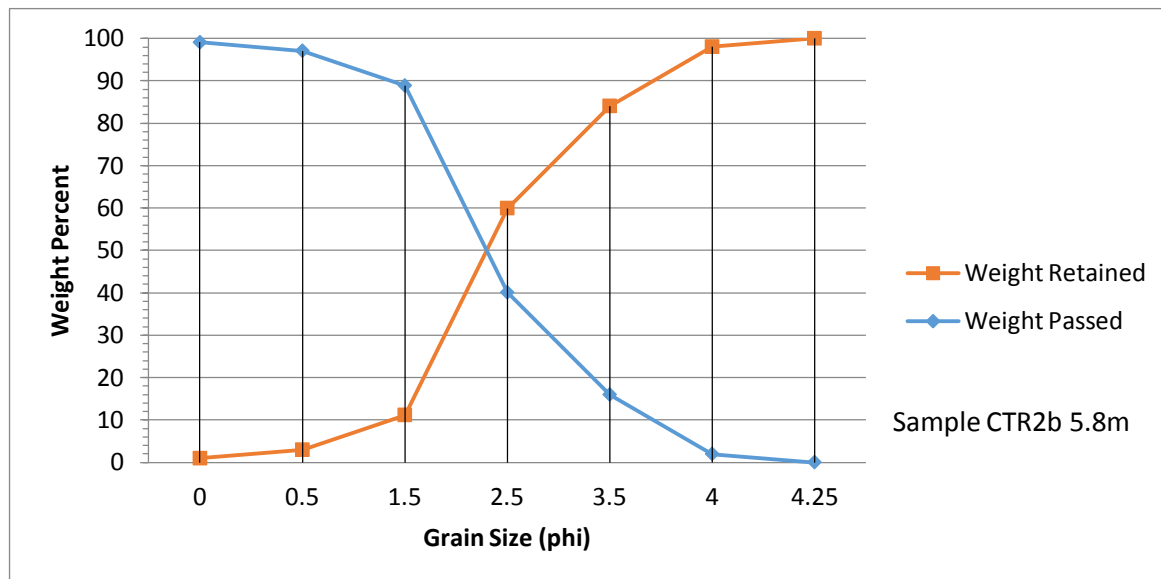


Table A.4 Sample from the first strata (5.8m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2c (6m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	0.3	1.02	1.03	98.97
0.71	0.5	1.8	6.11	2.05	97.95
0.355	1.5	13.35	45.28	8.16	91.84
0.18	2.5	7.48	25.37	53.44	46.56
0.09	3.5	5.5	18.65	78.81	21.19
0.063	4	0.75	2.54	97.46	2.54
0.053	4.25	0.3	1.02	100.00	0.00

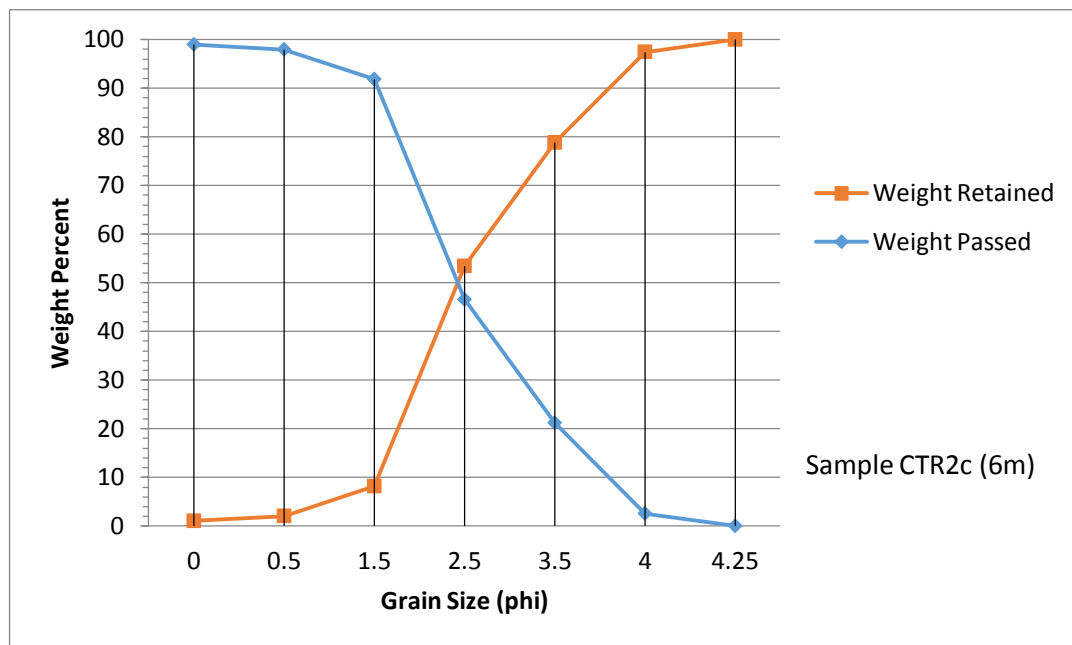


Table A.5 Sample from the first strata (6m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample 2d (7.31m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
2	-1	0	0.00	0.00	100.00
1	0	0.05	0.36	0.36	99.64
0.71	0.5	0.2	0.02	0.38	99.62
0.355	1.5	2.9	20.77	21.15	78.85
0.25	2	4.9	35.10	56.25	43.75
0.18	2.5	4.2	30.09	86.34	13.66
0.125	3.25	1	7.16	93.50	6.50
0.09	3.5	0.41	2.94	96.44	3.56
0.063	4	0.1	0.72	97.15	2.85
0.053	4.25	0.2	1.43	98.59	1.41

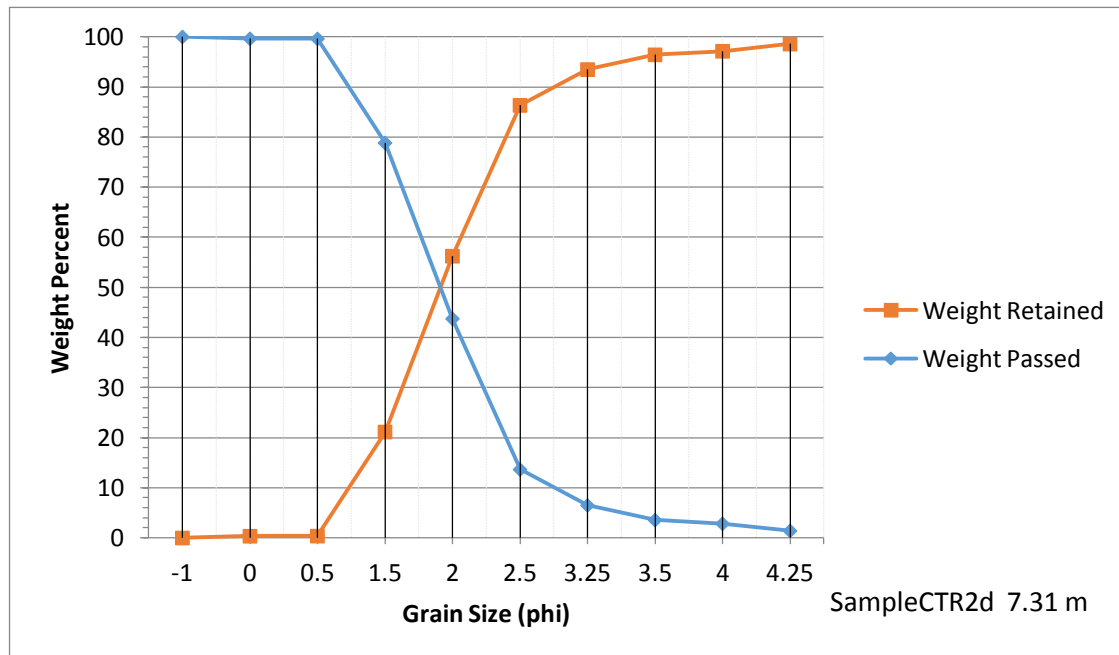


Table A.6 Sample from the first strata (7.31m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2e (7.34m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	1.53	4.46	4.46	100.00
0.71	0.5	3.5	10.00	14.57	90.00
0.355	1.5	20.8	60.59	75.16	29.41
0.18	2.5	7	20.39	95.55	9.02
0.09	3.5	1.5	4.37	99.92	4.65
0.063	4	0	0.00	100.00	0.00
0.053	4.25	0	0.00	100.00	0.00

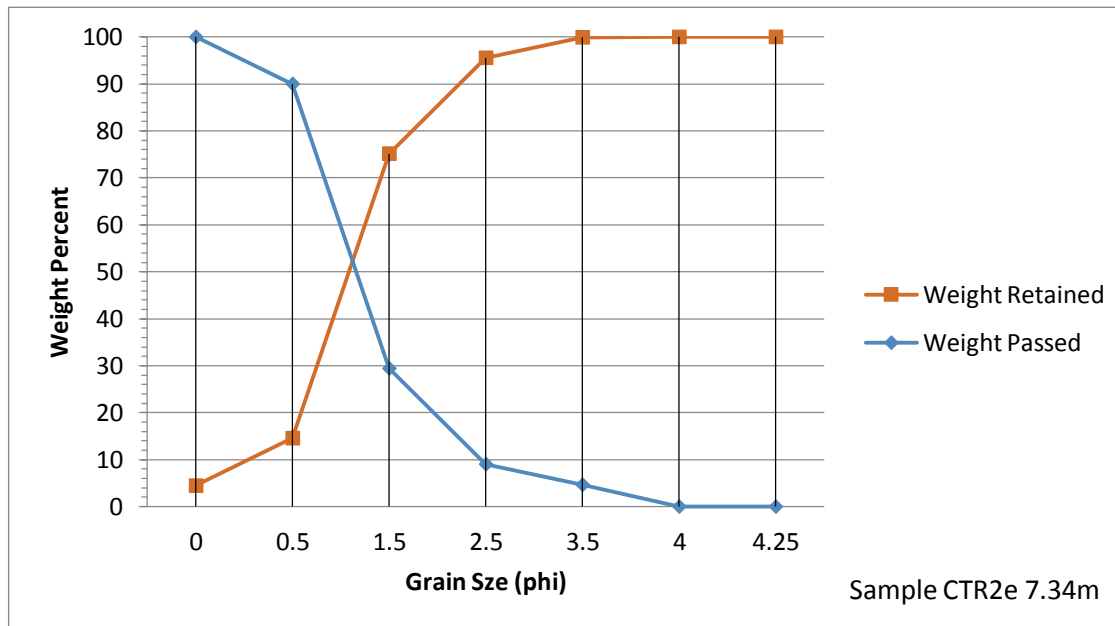


Table A.7 Sample from the first strata (7.34m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2f (7.56m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	0.85	2.75	2.75	97.25
0.71	0.5	1.88	6.09	8.84	91.16
0.355	1.5	11.4	36.92	45.76	54.24
0.18	2.5	10.75	34.81	80.57	19.43
0.125	3	3.85	12.47	93.04	6.96
0.09	3.5	1.26	4.08	97.12	2.88
0.063	4	0.69	2.23	99.35	0.65
0.053	4.25	0.20	0.65	100.00	0.00

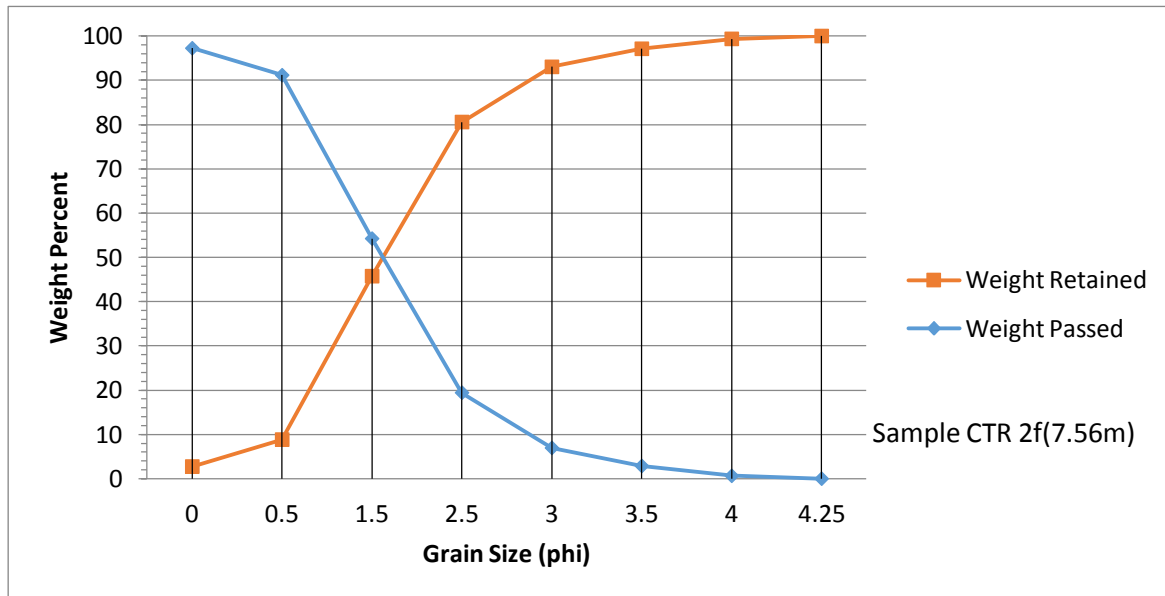


Table A.8 Sample from the first strata (7.56m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2g (7.59m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
1	0	0.85	2.25	2.25	100.00
0.71	0.5	0.59	1.56	3.82	98.44
0.355	1.5	1.86	4.93	8.75	93.50
0.18	2.5	9.5	25.20	33.95	68.30
0.063	4	20.9	55.44	89.39	12.86
0.051	4.25	4	10.61	100.00	2.25

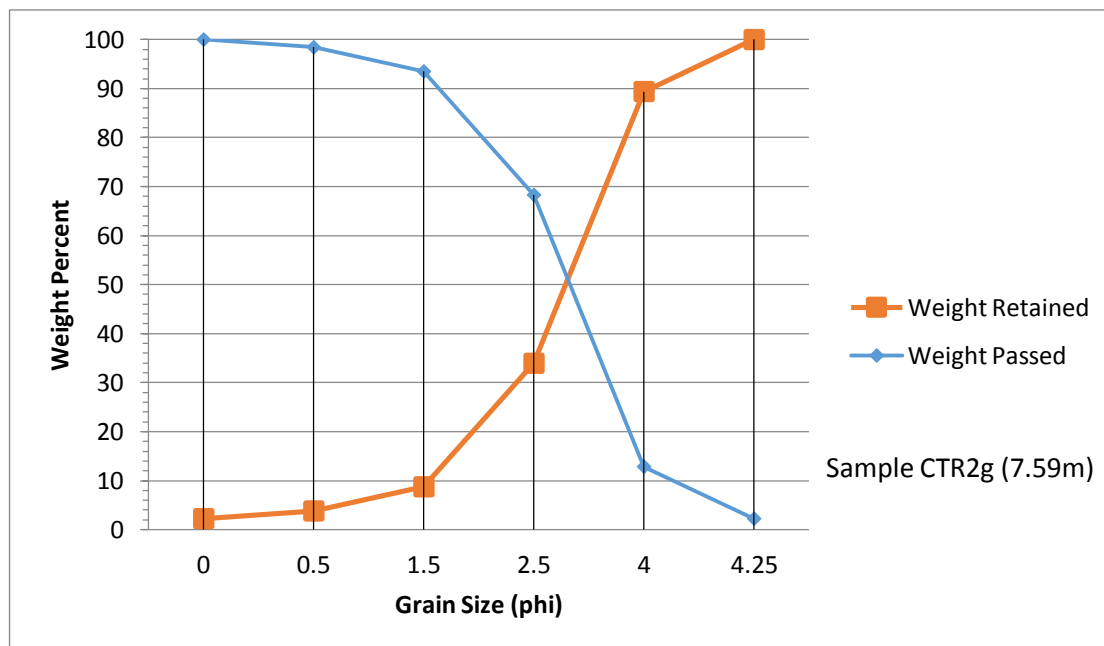


Table A.9 Sample from the first strata (7.59m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2h (7.9m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
2	-1	2	3.73	3.74	96.27
1	0	2.3	4.30	8.03	91.97
0.71	0.5	2.2	4.11	13.14	87.86
0.355	1.5	9.74	18.19	30.33	69.67
0.18	2.5	21.88	40.86	71.19	28.81
0.09	3.5	14.3	26.70	97.89	2.11
0.063	4	0.75	1.40	99.29	0.71
0.053	4.25	0.38	0.71	100.00	0.00

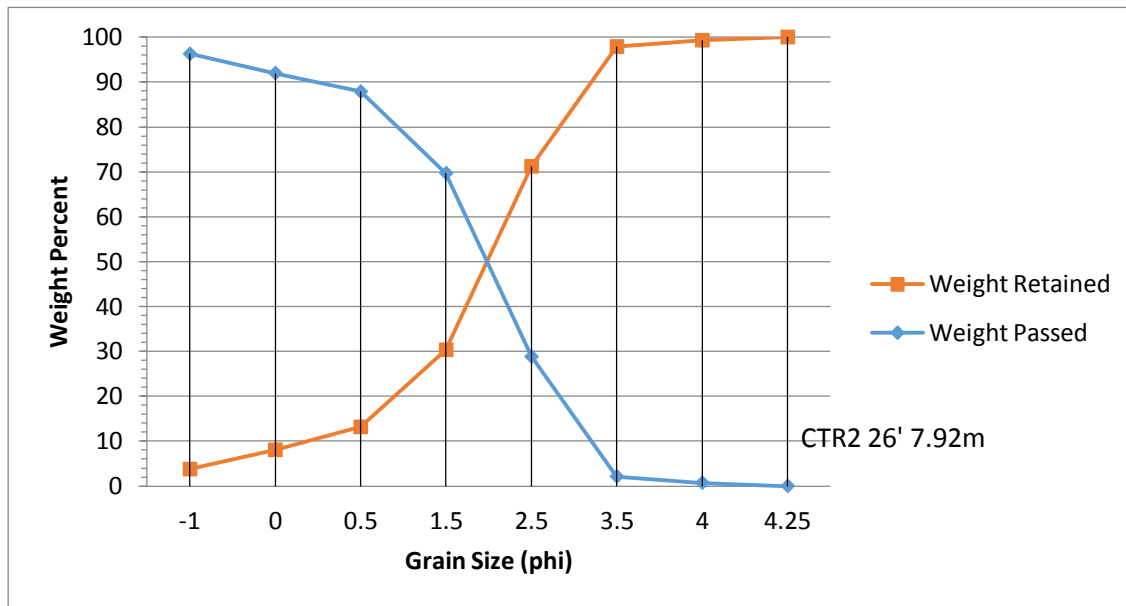


Table A.10 Sample from the first strata (7.92m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR2i (8.2m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
2	-1	3.65	9.30	0.18	100.00
1	0	5.31	13.53	9.48	92.52
0.71	0.5	5	12.74	23.01	78.99
0.355	1.5	13.15	33.51	35.75	66.25
0.18	2.5	9.35	23.83	69.27	30.73
0.09	3.5	2.55	6.50	93.09	6.91
0.063	4	0.16	0.41	99.59	0.41
0.053	4.25	0.07	0.18	100.00	0.00

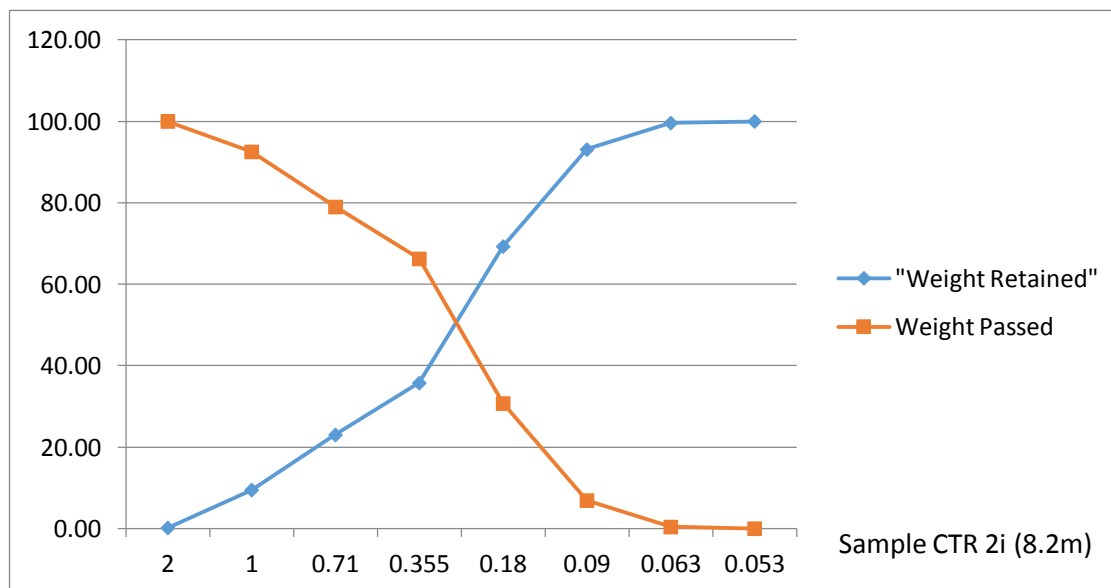


Table A.11 Sample from the first strata (8.2m) of core CTR2: cumulative weight percentages and derived frequency distribution curves.

Sample CTR3 (5m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Beaker with sand (grams)	Weight of beaker empty (grams)	Weight of Sand (grams)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
0.0625	4	33.2	31.1	2.1	0.18	18.00	0.00	93.00
0.053	4.25	34.2	31.1	3.1	0.26	26.00	26.00	80.00
0.044	4.5	33.4	31	2.4	0.20	20.00	46.00	64.00
0.037	4.75	33.3	31.4	1.9	0.16	16.00	62.00	52.00
0.0156	6	34.1	31.1	3	0.25	25.00	70.00	39.00
0.0078	7	33.39	30.7	2.69	0.22	22.00	87.00	24.00
0.0039	8	32.75	31.2	1.55	0.13	13.00	92.00	7.00
0.002	9	32.9	31	1.9	0.16	16.00	100.00	0.00

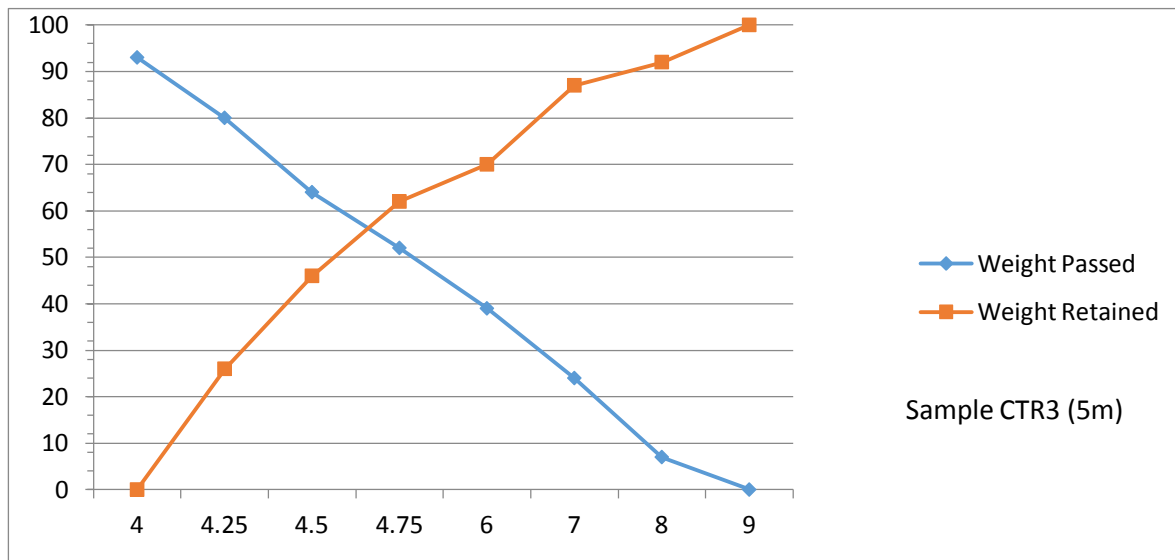


Table A.12 Sample from the first strata (5m) of core CTR3: cumulative weight percentages and derived frequency distribution curves.

Sample CTR4a (1.3m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Beaker with sand (g)	Weight of beaker empty (g)	Weight of Sand (g)	Weight of Size Fraction (g)	Weight Percent	Weight percentage each fraction * 100	Cumulative Weight % Retained	Cumulative Weight % Passed
2	-1	31.1	31.1	0	0.00	0.00	0.000	0.00	100.00
1	0	31.1	31	0.1000	0.10	0.01	0.991	0.99	99.01
0.71	0.5	31.3	31.1	0.1999	0.20	0.02	1.982	2.97	97.03
0.355	1.5	32.7	30.95	1.75	1.75	0.17	17.343	20.32	79.34
0.18	2.5	34.1	31.12	2.98	2.98	0.30	29.534	49.85	50.15
0.09	3.5	34.1	31.18	2.92	2.92	0.29	28.939	78.79	21.21
0.063	4	32	31.08	0.9200	0.92	0.09	9.117	87.91	12.10
0.053	4.25	31.9	30.68	1.22	1.22	0.12	12.091	100.00	0.01

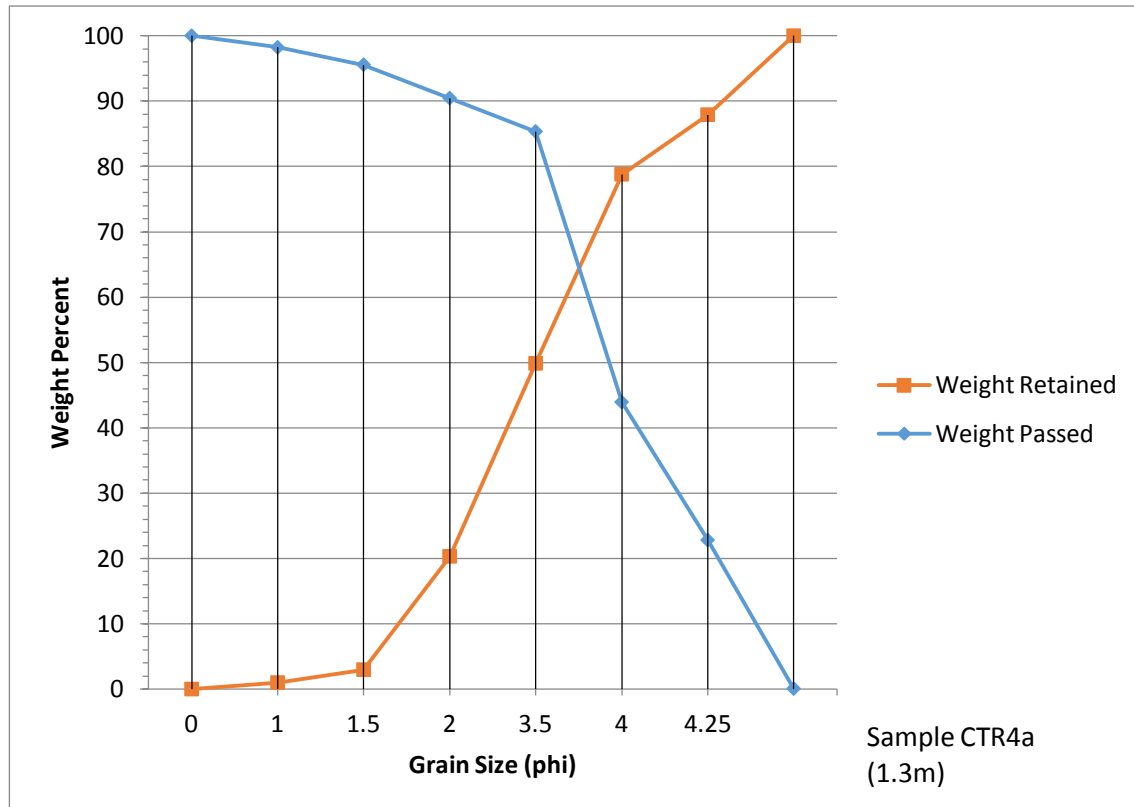


Table A.13 Sample from the first strata (1.3m) of core CTR4: cumulative weight percentages and derived frequency distribution curves.

Sample: CTR4b (6m)

Grain Size (mm)	Grain Size (ϕ)	Weight of Beaker with sand (g)	Weight of beaker empty (g)	Weight of Sand (grams)	Weight of Size Fraction (g)	Weight Percent	Cumulative Weight % Retained	Cumulative Weight % Passed
0.0625	4	32.8	31.3	1.5	0.13	13.00	0.00	93.00
0.053	4.25	33	31.1	1.9	0.16	16.00	13.00	80.00
0.044	4.5	32.6	31.2	1.4	0.12	12.00	25.00	64.00
0.037	4.75	32.9	31.3	1.6	0.13	13.00	38.00	52.00
0.0156	6	33.3	31.5	1.8	0.15	15.00	53.00	39.00
0.0078	7	33.2	31.2	2	0.17	17.00	70.00	24.00
0.0039	8	31.9	31	0.899	0.07	7.00	92.00	7.00
0.002	9	31.8	30.9	0.900	0.08	8.00	100.00	0.00

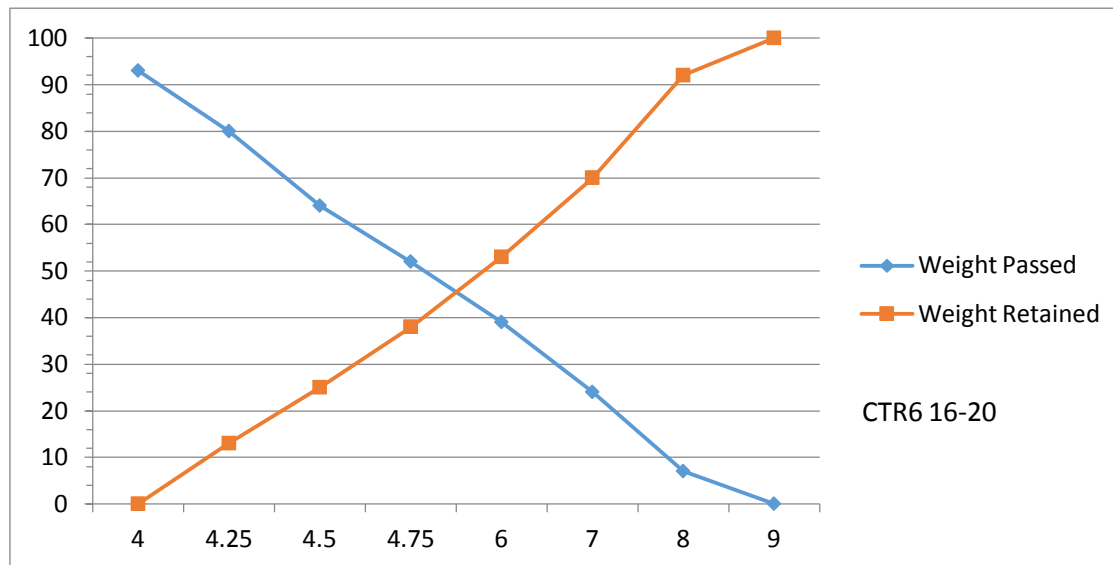


Table A.14 Sample from the first strata (6m) of core CTR4: cumulative weight percentages and derived frequency distribution curves.

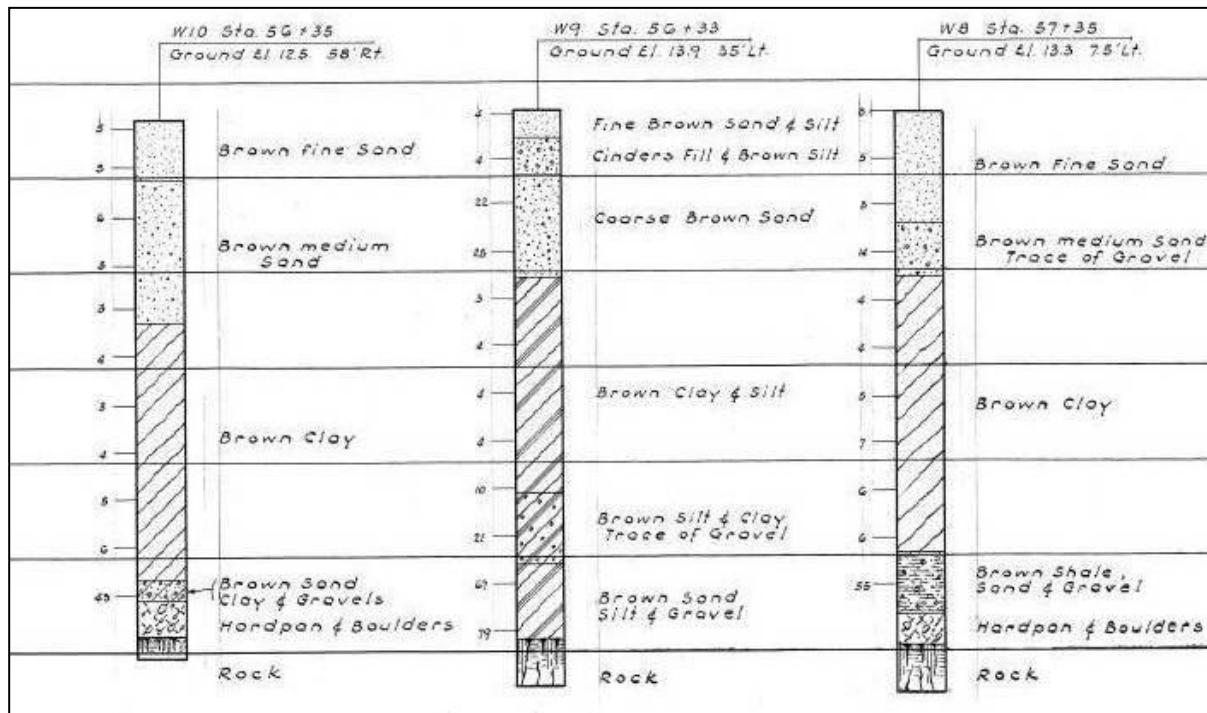


Figure A.15 Putnam Bridge Borings from west bank of Connecticut River (W10, W9, W8) From CTDOT Engineering Drawings 1955

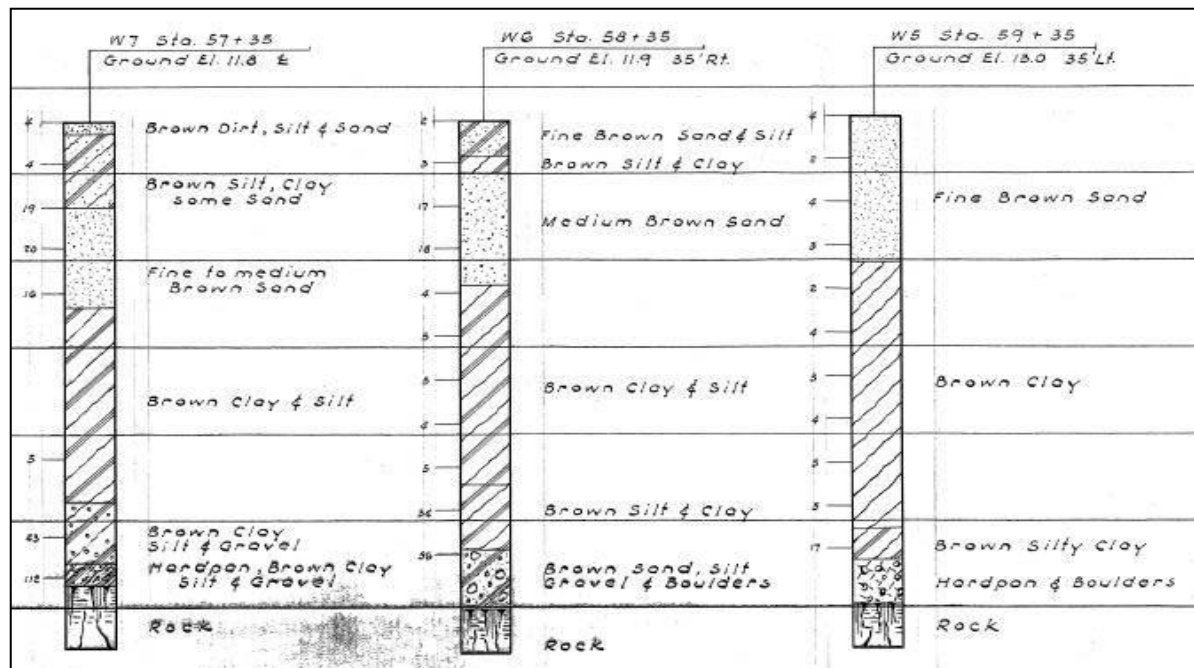


Figure A.16 Putnam Bridge Borings from west bank of Connecticut River (W7, W6, W5). From CTDOT Engineering Drawings 1955

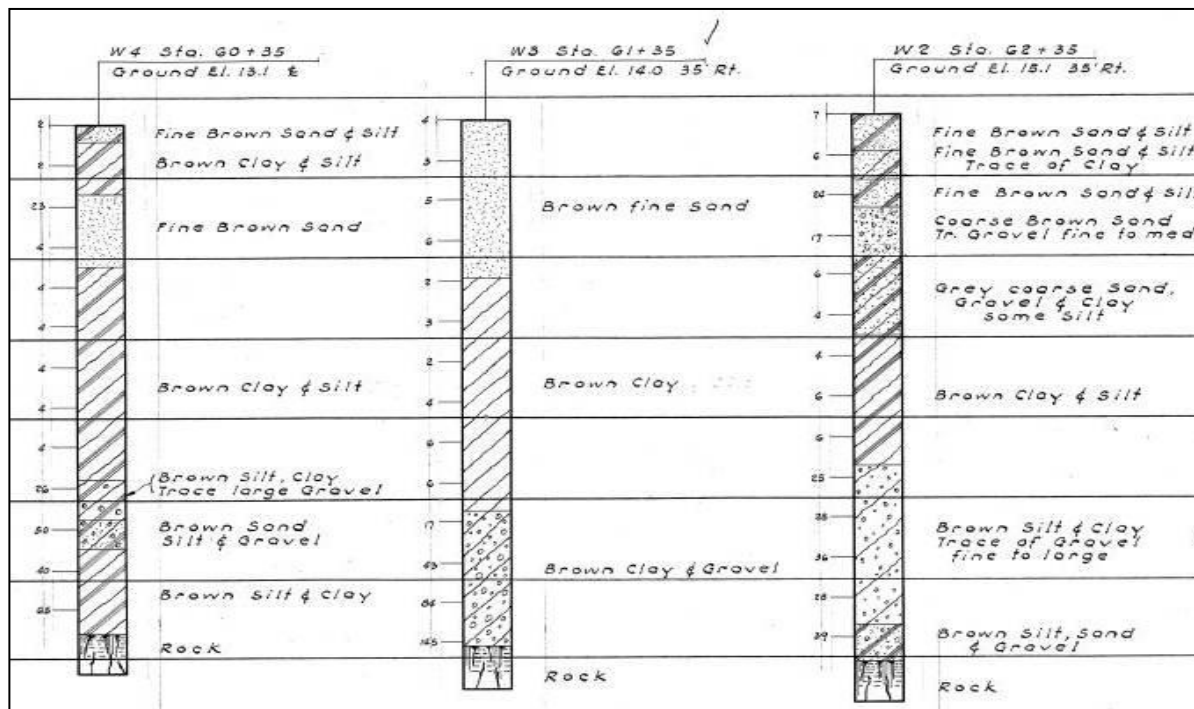


Figure A.17 Putnam Bridge Borings from west bank of Connecticut River (W4, W3, W2). From CTDOT Engineering Drawings 1055

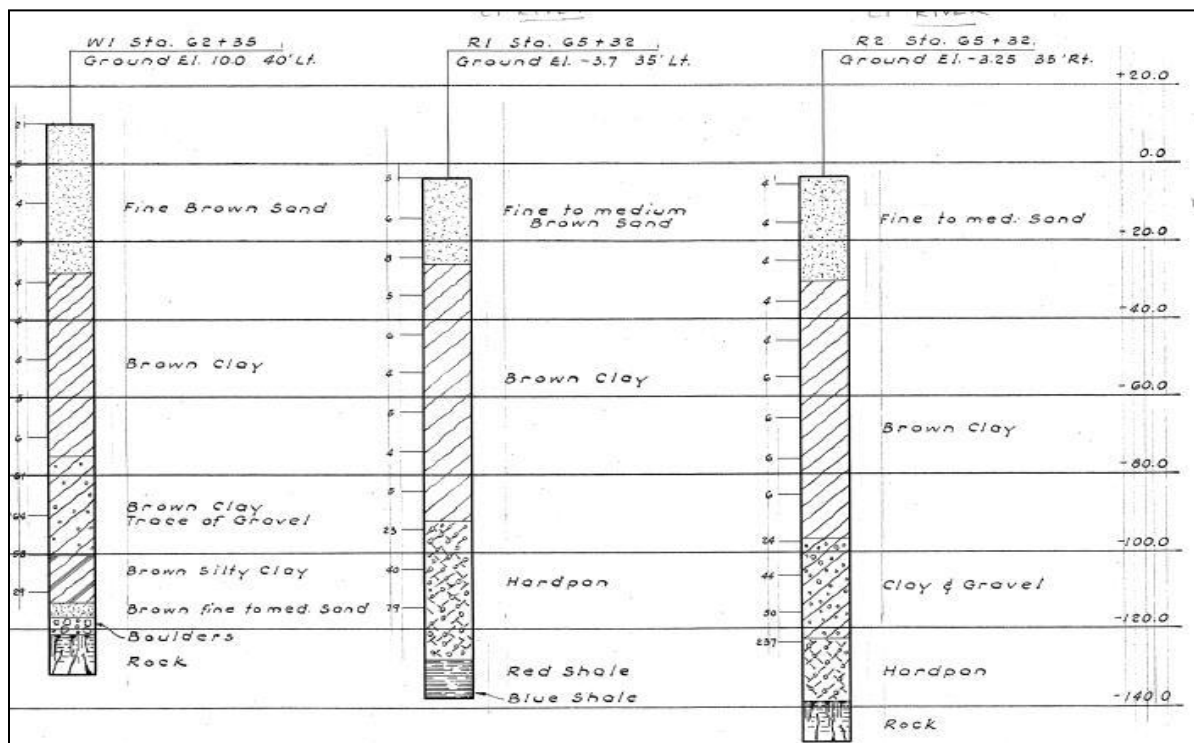


Figure A.18 Putnam Bridge Borings from west bank and Connecticut River (W1, R1, R2). From CTDOT Engineering Drawings 1955

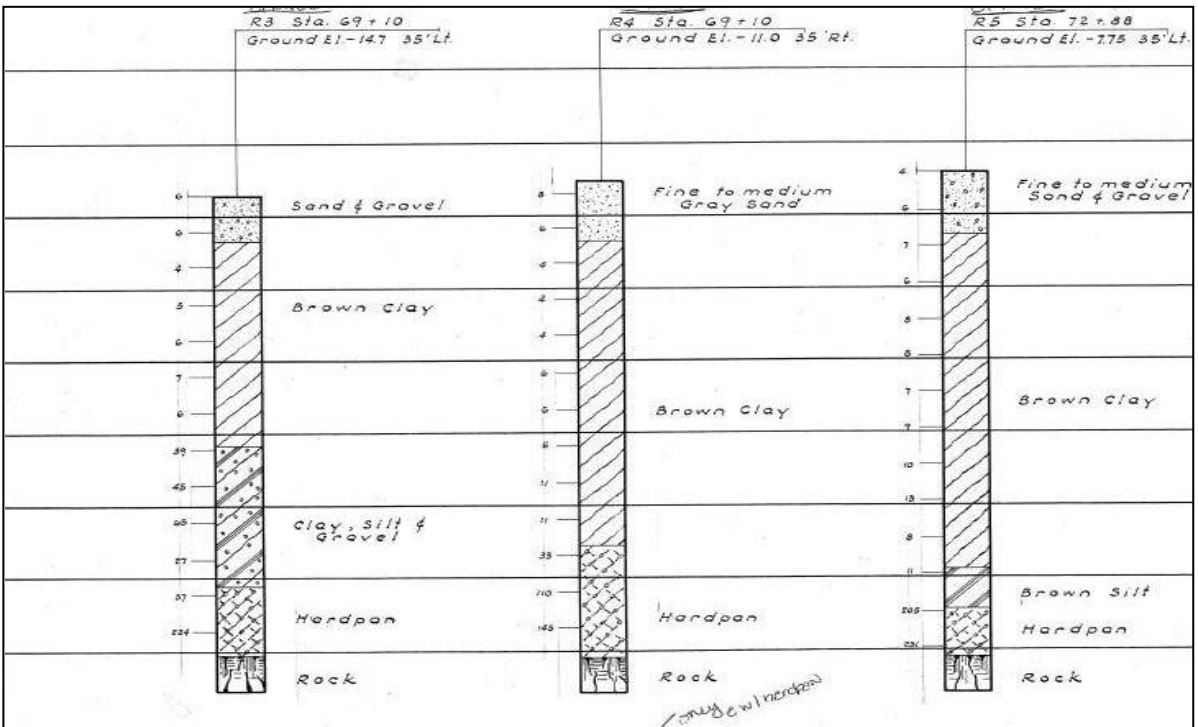


Figure A.19 Putnam Bridge Borings from the Connecticut River (R3, R4, R5). From CTDOT Engineering Drawings 1955

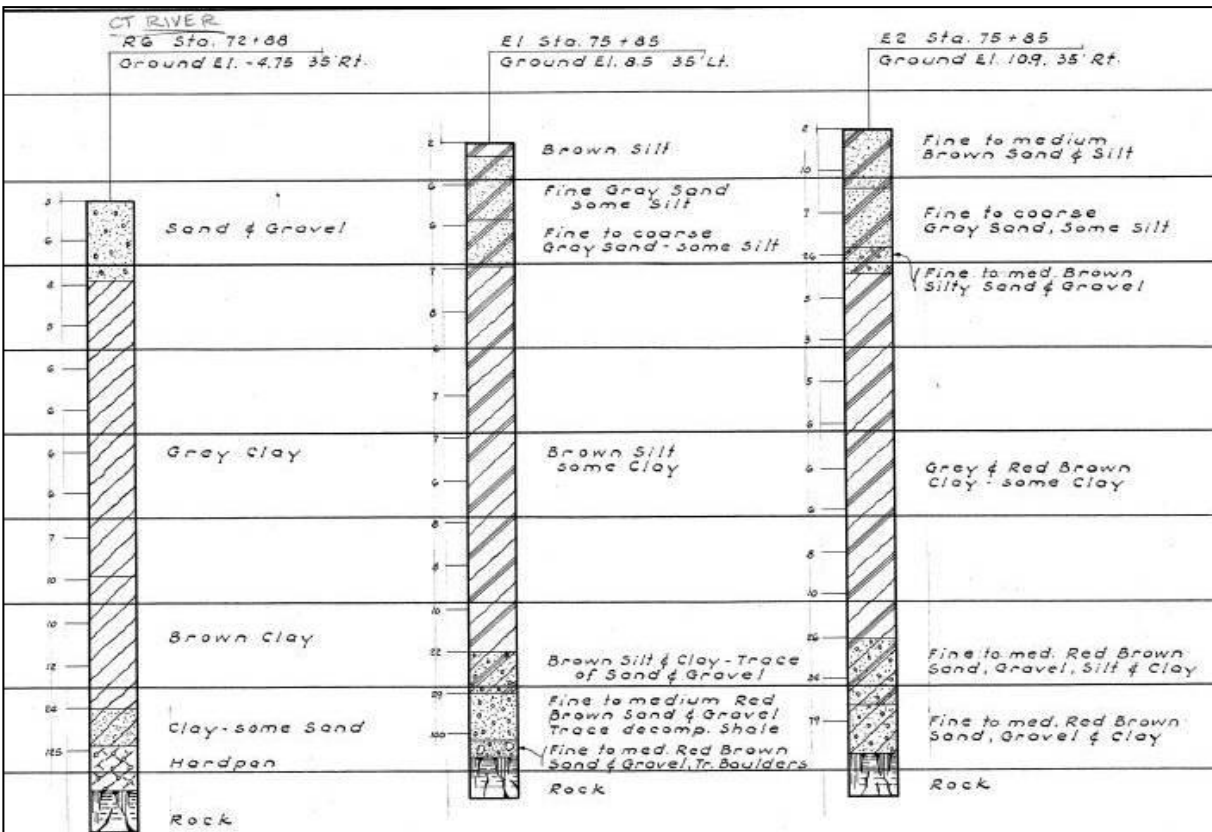


Figure A.20 Putnam Bridge Borings from the Connecticut River and east bank of the river (R6, E1, E2). From CTDOT Engineering Drawings 1955

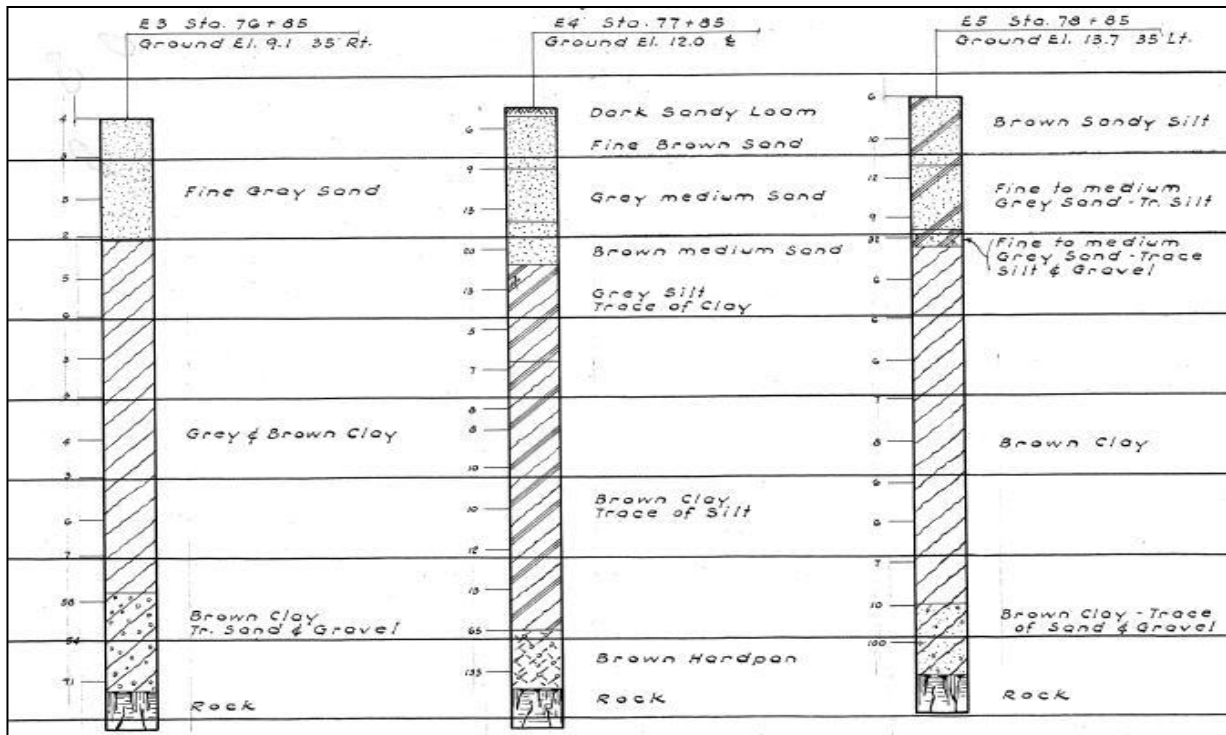


Figure A.21 Putnam Bridge Borings from the east bank of Connecticut River (E3, E4, E5). From CTDOT Engineering Drawings 1955

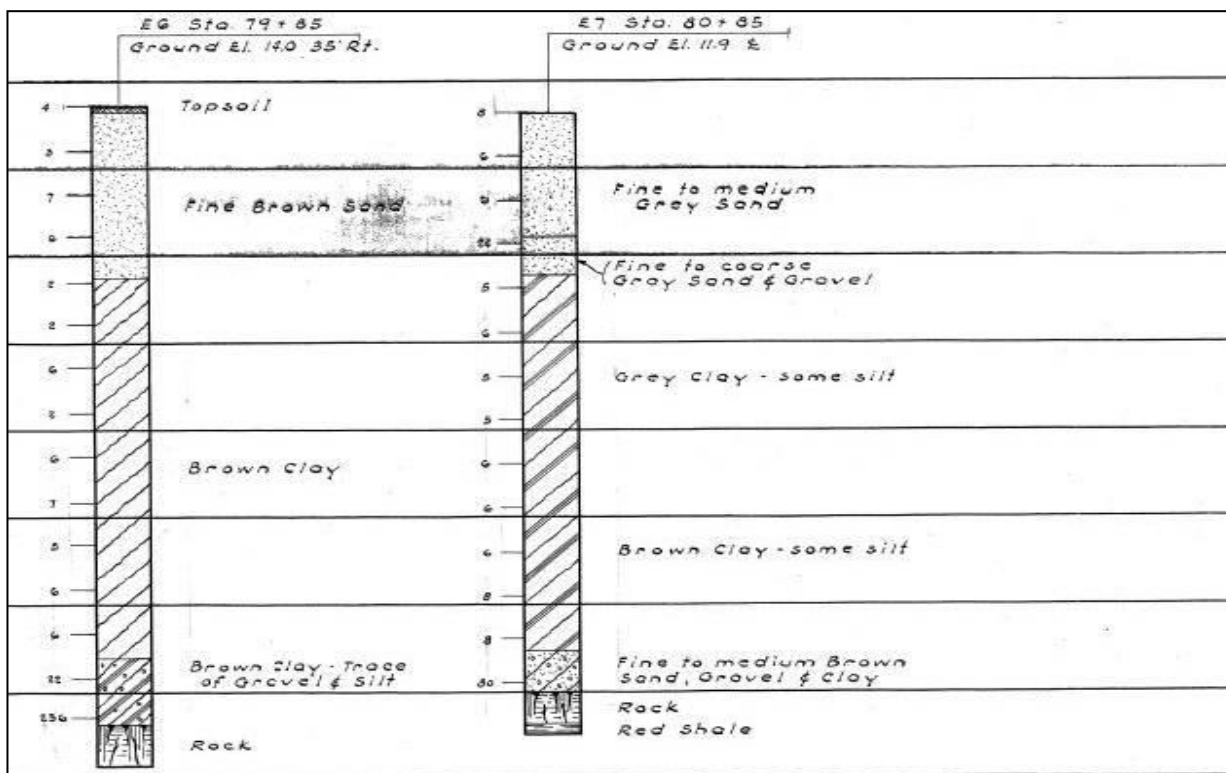


Figure A.22 Putnam Bridge Borings from the east bank of the Connecticut River (E6, E7). From CTDOT Engineering Drawings 1955

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